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Regional and subregional assessments of biodiversity and ecosystem services: regional and subregional assessment for Africa

Chapters of the regional and subregional assessment of biodiversity and ecosystem services for Africa

Note by the secretariat

1. In paragraph 2 of section III of decision IPBES-3/1, the Plenary of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) approved the undertaking of four regional and subregional assessments of biodiversity and ecosystem services for Africa, the Americas, Asia and the Pacific, and Europe and Central Asia (hereinafter referred to as regional assessments) in accordance with the procedures for the preparation of the Platform's deliverables set out in annex I to decision IPBES-3/3, the generic scoping report for the regional assessments of biodiversity and ecosystem services set out in annex III to decision IPBES-3/1, and the scoping reports for each of the four regional assessments (decision IPBES-3/1, annexes IV–VII).

2. In response to decision IPBES-3/1, a set of six chapters (IPBES/6/INF/3–6), together with a summary for policymakers (IPBES/6/4–7), were produced for each of the regional assessments by an expert group in accordance with the procedures for the preparation of the Platform's deliverables for consideration by the Plenary at its sixth session.

3. In paragraph 4 of section IV of decision IPBES-6/1, the Plenary approved the summary for policymakers of the regional assessment for Africa (IPBES/6/15/Add.1) and accepted the chapters of the assessment, on the understanding that the chapters would be revised following the sixth session as document IPBES/6/INF/3/Rev.1 to correct factual errors and to ensure consistency with the summary for policymakers as approved. The annex to the present note, which is presented without formal editing, sets out the final set of chapters of the assessment for Africa including their executive summaries.

4. A laid-out version of the final regional assessment report of biodiversity and ecosystem services for Africa (including a foreword, statements from key partners, acknowledgements, a preface, the summary for policymakers, the revised chapters and annexes setting out a glossary and lists of acronyms, authors, review editors and expert reviewers) will be made available on the website of the Platform prior to the seventh session of the Plenary.

Annex

Chapters of the regional assessment report on biodiversity and ecosystem services for Africa of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

Disclaimer on maps

The designations employed and the presentation of material on the maps used in this report do not imply the expression of any opinion whatsoever on the part of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystems Services concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein.

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Chapter 1: Setting the scene

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Executive Summary

Africa's extraordinary richness in biodiversity and ecosystem services, and wealth of indigenous and local knowledge, comprises a strategic asset for sustainable development in the region *(well-established)*. Africa is the last place on Earth with a broadly intact assemblage of mammalian megafauna. Africa has significant regional, subregional and national variations in biodiversity that reflect climatic and physical differences, as well as the continent's long and varied history of human interactions with the environment. This natural richness, accumulated over millions of years, coupled with the wealth of indigenous and local knowledge on the continent, is central to, and constitutes a strategic asset for, the pursuit of sustainable development in the region {1.1, 1.3.2, 1.3.9}.

Africa's rich and diverse ecosystems generate flows of goods and services that are essential in providing for the continent's food-, water-, energy-, health- and secure livelihood- needs *(well-established)*. Tangible assets such as food, water and medicinal plants, and intangible assets such as sacred sites and religious spaces underpin nature's contribution to the economy and are central to a multitude of other livelihood strategies. Nature's contributions to people are generally of immense benefit to the inhabitants of the continent and others across the globe, but can occasionally be detrimental as a result of losses or of conflicts over their uses {1.1.4, 1.3.1, 1.3.8.4}.

Africa has opportunities to fully realise the benefits of having such rich biodiversity and to explore ways of using it in a sustainable way to contribute to its economic and technological development *(established)*. Existing indigenous and local knowledge on management of biodiversity and nature's contributions to people appears to be declining in parts of the continent. It is important that the people of Africa do not lose both the rich natural resources and the indigenous and local knowledge to manage these resources, especially at a time when knowledge is increasingly recognised as vital to the development of a low carbon, ecological, knowledge-based economy {1.3.7, 1.3.9}.

Certain ecosystems found in Africa are of great ecological, biological and cultural importance at regional and global levels *(established but incomplete)*. As a strategic measure to protect them, as well as the species, knowledge and genetic resources they harbour, countries have declared 14% of the continent's land and 2.5% of the seas as protected areas, while some sites have been designated as wetlands of international importance; Important Bird and Biodiversity Areas; Alliance for Zero Extinction sites, where endangered or critically endangered species occur; ecologically and biologically significant marine areas; community conserved areas; United Nations Educational, Scientific and Cultural Organization World Heritage Sites; and Biosphere reserves {1.1.3, 1.3.6}.

Africa still does not know the full potential of biodiversity and of nature's contributions to its economic and technological development, and it continues to lose a large part of these resources and knowledge *(well-established)*. Addressing these gaps and losses is critical at a time when the value of knowledge is recognised as vital to the development of a low carbon, ecological, knowledge-based economy. Value of biodiversity and ecosystem services in itself, but also in its supporting function Africa's wealth in natural resources is increasingly needed to be understood. Further, existing knowledge around biodiversity and ecosystem services and indigenous resources appears to be on the decline in parts of the continent {1.3.4, 1.3.7, 1.3.9}.

1.1 Introduction

The importance of interconnections between nature and people for human livelihoods, food security, and a good quality of life cannot be overstated. Yet, all too frequently, concerns around biodiversity and ecosystem services take a secondary role to other political, economic and social considerations. This state of affairs is unsustainable. It leads to the erosion of resources and critical knowledge that are the foundation for a good quality of life, both now and into the future. The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was established in 2012 as a global response to the problem of declining biodiversity and ecosystem services, and the need for a credible evidence base to support policy making. Building on the previous work of the Millennium Ecosystem Assessment and the Intergovernmental Panel on Climate Change, IPBES specifically aims to strengthen knowledge foundations for better policy through science, for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development. One component of the IPBES work programme is the development of four policy-focussed regional assessments, including this one for Africa (Decision IPBES-3/1).

The Africa Assessment Report recognises the continent's global importance in terms of biodiversity and diversity in its peoples. As the cradle of humankind, Africa is where human-environment interactions have the longest history (Diop, 1981; Cann *et al.*, 1987; Malaspinas *et al.*, 2016; Mallick *et al.*, 2016; Pagani *et al.*, 2016) and where hundreds of millions of people still have a strong connection to nature and its multiple influences. Environmental factors—mainly those related to rainfall and net primary productivity—have been quantitatively associated with species variation and language richness (Moore *et al.*, 2002). In turn, population density in sub-Saharan Africa correlates with species richness for some taxa (Balmford *et al.*, 2001). This assessment illustrates, through a range of examples, the mutually beneficial interactions between nature and people, often supported by indigenous knowledge developed through generations (for example, Hammi *et al.*, 2010; Agidie *et al.*, 2014; Anderson *et al.*, 2014; Chibememe *et al.*, 2014; Blanco *et al.*, 2016). The value of interactions is already recognised through measures taken to respond to the well-established evidence of biodiversity loss and also to increase nature's contribution to people for a good quality of life for all. There are, nevertheless, also considerable threats and challenges from intricately woven and, often, mutually reinforcing drivers of land-use change, biodiversity loss and ecosystem degradation. The ultimate objective of the Africa regional assessment is to draw together what is currently known about the state and dynamics of African biodiversity and ecosystem services. This serves to help policymakers and practitioners to better recognise, value, protect and enhance nature and its benefits to Africans as we endeavour to eliminate poverty and emerge as a new economic and social force. Achieving better responses will require new perspectives and collaborations. This assessment marks an important step in the process of achieving these goals.

1.1.1 Purpose and scope of this assessment

The Africa regional assessment is one of the regional assessments being conducted under the umbrella of IPBES. The assessment is a critical evaluation of the state of knowledge of biodiversity and ecosystem services, as requested by governments and relevant stakeholders. Its purpose is to identify key priorities that will help policymakers develop policy solutions which meet the needs of the Africa region as a whole, as well as those of its five subregions and their national constituents. The assessment and the policy options that it outlines will help African Governments and institutions develop strategies to meet sustainability and conservation goals. Some of the most important of these are the Strategic Plan for Biodiversity 2011–2020 and its Aichi Biodiversity Targets, the national biodiversity strategies and action plans developed under the Convention on Biological Diversity (CBD), the African Aspirations for 2063, and the 2015–2030 Sustainable Development Goals (SDGs). The chapters in this assessment, therefore, make explicit reference to each of these strategies, targets and goals.

The overall scope of the regional and subregional assessments is to assess the status and trends of terrestrial, freshwater, coastal and marine biodiversity, ecosystem functions and ecosystem services together with their inter-linkages. The assessment also considers the impact of biodiversity, ecosystem functions and ecosystem services on quality of life and the effectiveness of responses to date. To this end, the contributors to the Africa Assessment Report have synthesized and critically judged existing knowledge. It is important to note that the Africa Assessment did not undertake original research. In accordance with the function of an assessment, it uses reliable sources of knowledge and information drawn from peer-reviewed literature and important grey literature, as well as indigenous and local knowledge (ILK) sources. The process of evaluating the state of knowledge helps to further identify key knowledge gaps and uncertainties, the associated implications for effective policy making, and the steps required to address them. The assessment consequently aims to achieve a broad readership and to provide the foundation for a meaningful dialogue across the full range of actors involved in African development.

Key policy-relevant questions underpinning the Africa Assessment are as follows:

- How do biodiversity and ecosystem functions and services contribute to the economy, livelihoods, food security, and good quality of life in the region, and what are the interdependencies among them?
- What are the status, trends and potential future dynamics of biodiversity components (i.e., plants, animals, microorganisms and ecosystems) that affect nature's contributions to people in the different regions of Africa, (such as ecosystem functions and services) that affect their contribution to the economy, livelihoods and well-being in the region?
- What are the pressures driving the change in the status and trends of biodiversity, ecosystem functions, ecosystem services and good quality of life in the region?
- What gaps in knowledge need to be addressed in order to better understand and assess drivers, impacts and responses of biodiversity, ecosystem functions and services at the regional level?
- What are the scenarios and related policy ideas and options for decision-makers at the regional and subregional levels; how effective are they and what policy environment would best ensure success of these options?
- What are the actual impacts of, and potential pathways for policies and interventions regarding the contribution of biodiversity and ecosystem services to the sustainability of the economy, livelihoods, food security and good quality of life in the region?
- What role do government, bureaucratic and political institutions play in advancing public policies to improve the quantity and quality of biological resources alongside other national priorities through mainstreaming biodiversity and ecosystem services?

In addition to these questions, the Africa Assessment considers a number of key thematic challenges including (but not limited to) the food-energy-water-livelihood nexus; health; climate change; land degradation; sustainable use and conservation; and invasive species. The assessment pays particular attention to questions of equity, rights, social relationships, spirituality and cultural identity/diversity in its investigation of biodiversity, ecosystem functions and nature’s contributions to people. Given the critical backdrop of economic transition, the Africa Assessment further considers the impacts of trade and investment, as well as carbon smart prospects for green-blue transformations in the economy. By green-blue transformations, we refer to productivity gains and industrial innovations using renewable resources and energies, as well as local competencies and solutions—particularly those based on the untapped wealth of terrestrial and marine ecosystems. For green-blue transformations to succeed, they must protect the rights and livelihoods of those living in and dependant on terrestrial and marine ecosystems in Africa. Equally, a future vision for Africa cannot omit consideration of human and environmental health. Careful consideration is thus given to the connection between human health and nature, as determined through biodiversity and critical ecosystem functions. Finally, this assessment acknowledges that baseline evidence and knowledge of what needs to happen is seldom enough to affect real change. Therefore, we also assess institutional capacity to lead and bring about desired conservation outcomes. As part of this, we seek to understand the degree of independence that decision-makers have over internal impacts on biodiversity and ecosystem services within the region as one of the key factors that determines capacities to develop effective responses.

Due to IPBES being an interdisciplinary collaboration, it has been necessary to develop a standardised framework (Figure 1.1) to guide and structure its assessments. The framework identifies and links the people and nature components of the system being assessed. It also provides common terminology for use across IPBES assessments and proposes assumptions about key relationships in the system. Figure 1.1 is a simplified version of the figure adopted by the second session of the Plenary of IPBES (UNEP, 2014), and modified by the fifth session of the Plenary (UNEP, 2017). A more complete description of all elements and linkages, together with examples, is presented in Díaz *et al.* (2015).

1.1.2 Background on Biodiversity and Ecosystem Services

The authors in the assessment use the terms "Nature's Contributions to People" (NCP) (Pascual *et al.*, 2017) and "Biodiversity and Ecosystem Services" (Díaz *et al.*, 2015) throughout the report. The latter is defined by Díaz *et al.* (2015) as follows (more on NCP later in this section):

- Biodiversity is shorthand for biological diversity. The Convention on Biological Diversity defines biodiversity as: "The variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species ("genetic diversity"), between species and ecosystems."
- Biodiversity underpins the functioning of ecosystems. The Convention on Biological Diversity in its article 2 identifies an ecosystem as "a dynamic complex of plant, animal and micro-organism communities and the non-living environment interacting as a functional unit".
- Ecosystems provide a range of services as part of the wider contributions people receive from nature. The Millennium Ecosystem Assessment (MA, 2005) divided ecosystem services into four broad areas (see examples in Table 1.1):
    - Provisioning services (e.g., food, freshwater, timber),
    - Regulating services (e.g., climate regulation, pollination),
    - Cultural services (e.g., recreation, spiritual values), and
    - Supporting services that underpin these other three types.

Scientists have attempted to construct typologies of ecosystem services that assign different types of service to different categories. The Millennium Ecosystem Assessment (MA, 2005) recognised four categories of ecosystem services (Figure 1.2). With debates over the years, these categories have been reduced to three broad areas with various explanations. For instance, Haines-Young *et al.* (2010) contend that 'supporting services' are "structures, processes and functions characterising ecosystems", therefore should be excluded from the categories of ecosystem services.

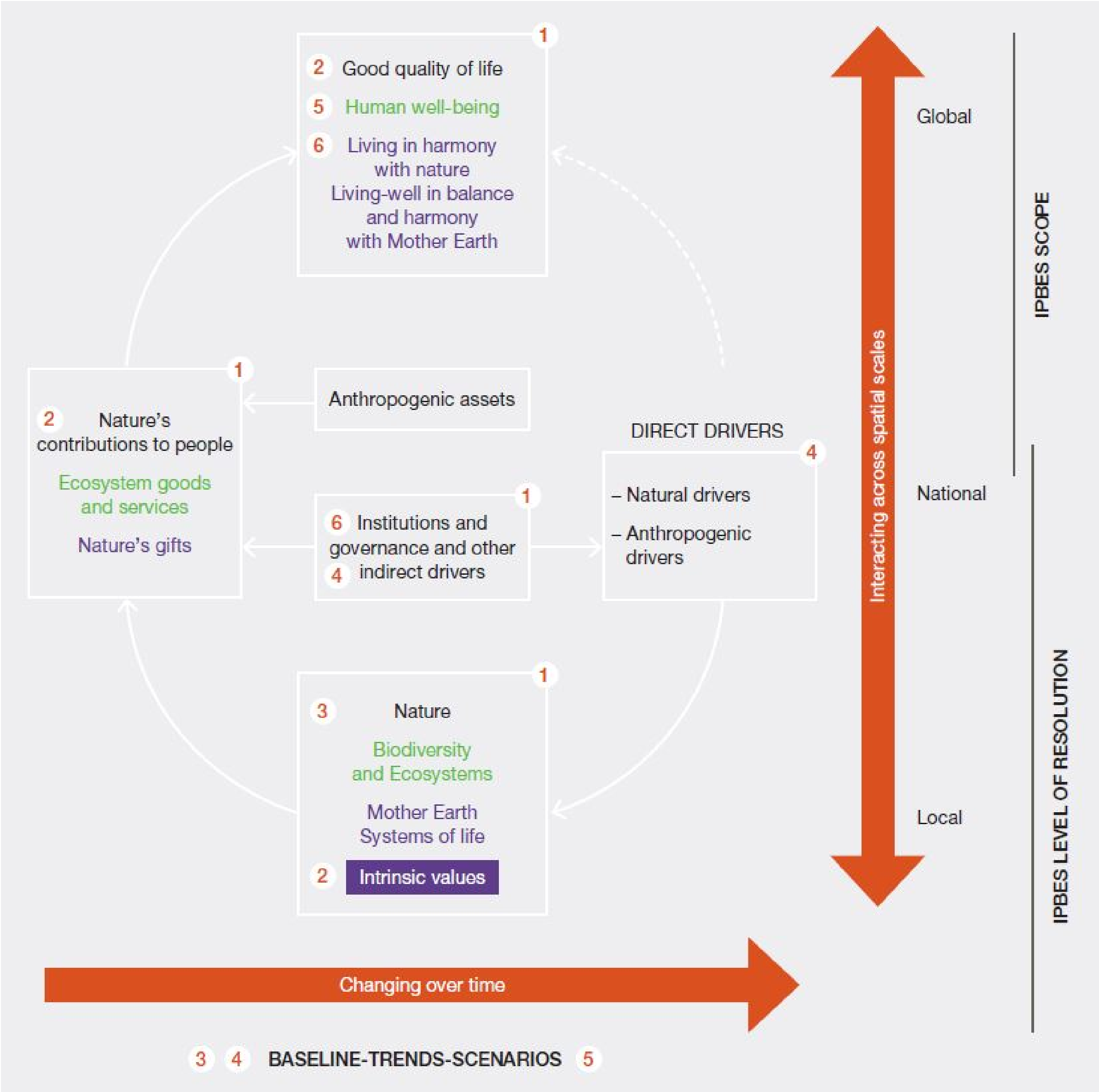


Figure 1.1: The IPBES Conceptual Framework. The boxes and arrows denote the elements of nature and society. Headlines in black within each box are inclusive categories relevant to all IPBES stakeholders and embrace the categories of science (in green) and comparable or similar categories according to other knowledge systems (in purple). Solid arrows denote influence between elements included in IPBES (the dotted arrows denote links that are acknowledged as important, but are not the main focus of IPBES). Interactions between the elements change over time (horizontal broad orange arrow) and occur at various spatial scales (vertical broad orange arrow). Orange numbers refer to chapters where more information on the topic can be found. Source: Díaz *et al.* (2015).

IPBES now distinguishes three broad groups of NCP (Figure 1.2): regulating, material and non-material. These represent different facets of the complex flow from nature to a good quality of life ranging from indispensable direct biological connections, such as oxygen, water, calories and vitamins without which the physical existence of humans is not possible, all the way to the anchoring of the symbolic components that give meaning to the identity of different social groups and their relationships with nature. Rather than an abrupt departure from previous classifications, the present broad categorisation of NCP is an evolution, still strongly rooted in the Millennium Ecosystem Assessment and its system of categorisation of ecosystem services (MA, 2003; MA, 2005). It reflects some key improvements to the original Millennium Ecosystem Assessment classification, based on more than a decade of progress in interdisciplinary thinking, with increasing involvement from the social sciences and humanities (including law, economics and policy).

Table 1.1: A typology of nature's contributions to people and their ecological characteristics. Source: adapted from Kremen (2005).

Nature's contribution	Ecosystem service providers/trophic level	Functional units	Spatial scale	Potential application to ecological studies
Aesthetic, cultural	All biodiversity	Populations, species, communities, ecosystems	Local–global	Low
Ecosystem goods	Diverse species	Populations, species, communities, ecosystems	Local–global	Medium
UV protection	Biogeochemical cycles, micro-organisms, plants	Biogeochemical cycles, functional groups	Global	Low
Purification of air	Micro-organisms, plants	Biogeochemical cycles, populations, species, functional groups	Global-regional	Medium (plants)
Flood mitigation	Vegetation	Communities, habitats	Local–regional	Medium
Drought mitigation	Vegetation	Communities, habitats	Local–regional	Medium
Climate stability	Vegetation	Communities, habitats	Local–global	Medium
Pollination	Insects, birds, mammals	Populations, species, functional groups	Local	High
Pest control	Invertebrate parasitoids and predators and vertebrate predators	Populations, species, functional groups	Local	High
Purification of water	Vegetation, soil micro-organisms, aquatic micro-organisms, aquatic invertebrates	Populations, species, functional groups, communities, habitats	Local–regional	Medium to high
Detoxification and decomposition of wastes	Leaf litter and soil invertebrates, soil micro-organisms, aquatic micro-organisms	Populations, species, functional groups, communities, habitats	Local–regional	Medium
Soil generation and soil fertility	Leaf litter and soil invertebrates, soil micro-organisms, nitrogen-fixing plants, plant and animal production of waste products	Populations, species, functional groups	Local	Medium
Seed dispersal	Ants, birds, mammals	Populations, species, functional groups	Local	High

1.1.3 Global importance and uniqueness of biodiversity in Africa

Africa has many biodiversity hotspots and globally important ecoregions (Box 1.1), but it is important to note that biodiversity is unevenly distributed across the continent (Linder, 2014). Designated biodiversity hotspots are distributed all over Africa, from the Cape Floristic Region, the Maputaland-Pondoland-Albany area and the Succulent Karoo in South Africa to the Mediterranean Basin, the Coastal Forests and Afromontane regions of Eastern Africa, the Guinean Forests in West Africa, the Horn of Africa, as well as Madagascar and the Indian Ocean Islands (Mittermeier *et al.*, 2004; Taylor, 2015).

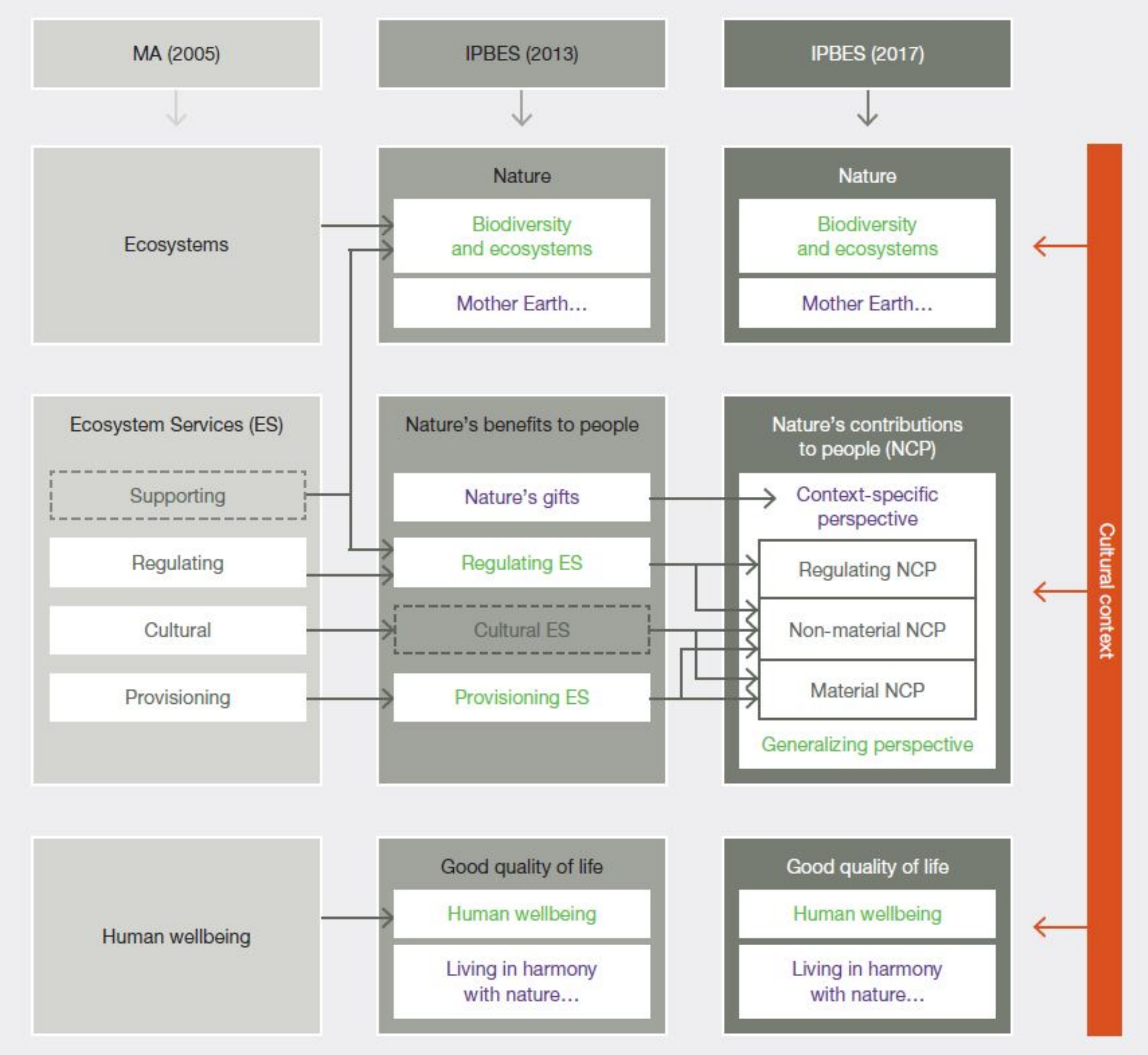
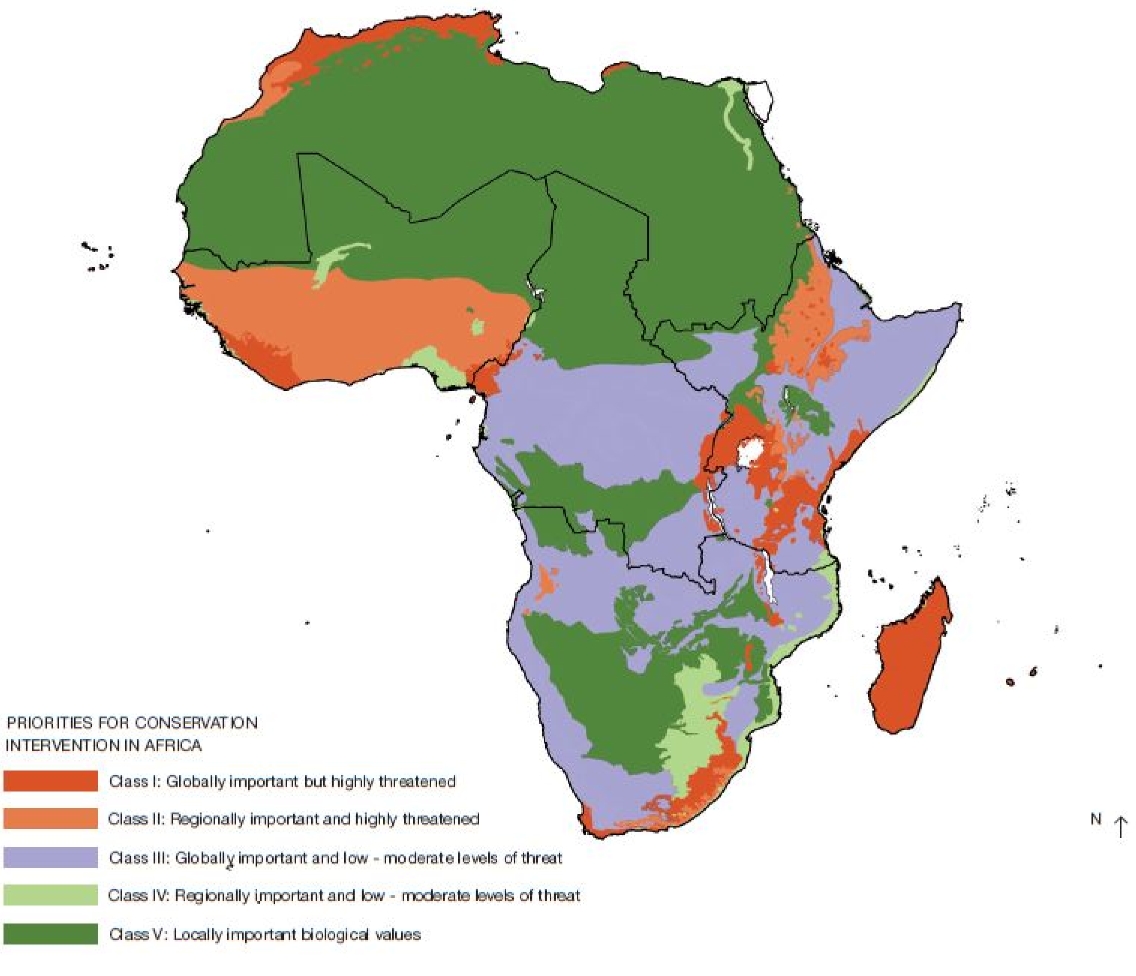


Figure 1.2: Evolution of nature's contributions to people (NCP) and other major categories in the IPBES conceptual framework with respect to the concepts of ecosystem services and human well-being as defined in the Millennium Ecosystem Assessment. The element "nature's benefit to people" was adopted by IPBES Second Plenary, and further developed into NCP by IPBES Fifth Plenary in order to fully capture the fact that the concept includes all contributions to people, both positive (benefits) and negative (detriments). Concepts pointed by arrow heads replace or include concepts near arrow tails. Concepts in dotted-line boxes are no longer used: following the present view of the MA community, supporting ecosystem services are now components of nature or (to a lesser extent) regulating NCP. Cultural ecosystem services was defined as a separate ecosystem service category in the MA; IPBES instead recognises that culture mediates the relationship between people and all NCP. Source: Díaz *et al.* (2018).

Burgess *et al.* (2006) further identified five classes of ecoregion priorities on land and across the 113 ecoregions in Africa. Based on freshwater biodiversity (mostly fish), Abell *et al.* (2008) highlighted 830 ecoregions worldwide, among which 87 are in Africa. Beaumont *et al.* (2011) showed that the Guinean moist forests and several other tropical and subtropical terrestrial ecoregions in Central, Southern and Eastern Africa ranked among areas of "exceptional biodiversity". This is true also for deserts, Succulent Karoo, Fynbos, lakes, great rivers, wetlands, coastal and mineral-rich areas, all exhibiting great biological diversity and playing important roles in food security. Important biodiversity

Box 1 1 African biodiversity conservation priorities. Sources: map adapted from Olson *et al.* (2001); Burgess *et al.* (2006).

The location of and threats to biodiversity are unevenly distributed, thus it is important to prioritise conservation efforts to minimise biodiversity loss and maintain ecosystem services (Brooks *et al.*, 2006; Burgess *et al.*, 2006). Brooks *et al.* (2006) analysed all nine major global biodiversity conservation priority templates, i.e. 1) Crisis Ecoregions; 2) Biodiversity Hotspots; 3) Endemic Bird Areas; 4) Centers of Plant Diversity; 5) Megadiversity Countries; 6) Global 200 Ecoregions; 7) High-Biodiversity Wilderness Areas; 8) Frontier Forests; and 9) Last of the Wild, from which they developed two possible approaches to biodiversity conservation. Approaches comprised: 1) Prioritizing areas of high threat and high irreplaceability and 2) Prioritizing areas of low threat but high irreplaceability. Burgess *et al.* (2006) came up with a similar ecoregion prioritisation, i.e. 1) highly threatened ecoregions with many endemic species that require proactive actions to prevent further habitat loss and extinctions, and 2) less threatened ecoregions that require conservation of large areas that will support large-scale habitat processes and associated species. Burgess *et al.* (2006) further identified five classes of ecoregion priorities.



A method to focus this large scale conservation priority approach to a regional or national level is the identification and establishment of Key Biodiversity Areas (KBAs) to increase the coverage of protected areas in support of the Aichi biodiversity targets (CBD, 2013). Given the importance of freshwater, KBAs have been identified across continental Africa and conservation planning software used to prioritize a network of catchments that includes 99% of the total species (Holland, 2012). In addition to this concept, the Red List of Ecosystems (RLE) was recently developed to assess risks to biodiversity and ecosystem functioning (Rodriguez *et al.*, 2015). A large regional gap is the identification of conservation priorities for the coastal and offshore marine habitats and species.

areas in Africa encompass a wide range of biomes and landscape features. These areas are generally diverse in endemic animal species of global importance (for example, chimpanzee and gorilla species), but are also extremely rich in plants, reptiles, amphibians, birds and invertebrates. The biodiversity hotspots contain important ecosystems that are repositories of biodiversity and ecosystem services, notably the provision of water to lowland communities and the maintenance of lake systems.

There are 75 United Nations Educational, Scientific and Cultural Organization Man and Biosphere reserves in 28 countries in Africa (UNESCO, 2017). As for biodiversity hotspots, examples include the northern margin of Africa which is part of the Mediterranean Basin biodiversity hotspot, comprising the second largest hotspot in the world and the largest of the world's five Mediterranean-climate regions covering more than 2 million km^2 (CEPF, 2015). The Mediterranean Basin Forest that constitutes just 1.5% of the world's forests, yet is home to 25,000 plant species and 14 endemic genera (Quézel *et al.*, 1999). According to Harrison *et al.* (2016), the Congo Basin, the second largest humid forests ecosystem after the Amazon Basin covers 4 million km^2. It is home to over 1,200 fish species, 400 mammal species, 1,000 bird species, and over 10,000 vascular plant species, as well as providing about 30% of Africa's freshwater resources, with an estimated 77 million people in the Congo basin relying on these natural resources.

1.1.4 Links between biodiversity and ecosystem services, and human well-being in Africa

No matter who we are, or where we live, our well-being depends on functioning ecosystems. Most obviously, ecosystems can provide us with material objects that are essential for, and improve, our daily lives; such as food, beverages, housing, furniture, cosmetics, and medicines. Although the other types of ecosystem contributions are easily overlooked, they play an important role in shaping human cultures and regulating the environments in which we live. They help ensure the flow of clean water and protect people from flooding and other hazards like soil erosion, landslides and tsunamis. These ecosystems often have deep cultural or religious significance and are of paramount importance in the spiritual well-being of Africans. In addition, they provide the opportunities for recreation or the enjoyment of nature (Haines-Young et al, 2010). Well-conserved ecosystems also have the potential to significantly improve human health and well-being (Myers *et al.*, 2013; Finlayson *et al.*, 2015).

1.2 Methodology

1.2.1 Basic methods and approaches used in the assessment

In accordance with IPBES prescriptions as stated in IPBES deliverables (Box 1.2), all IPBES assessments must be based on data and knowledge resources that are:

- Fully referenced and for which all contributions are appropriately attributed and recognised;
- Comprehensively documented in underlying sources and methodologies and that adhere to domain-specific meta-data standards; and
- Archived and accessible to IPBES experts and, wherever possible, the public.

The methodologies and approaches used in the regional assessment for Africa have followed these rules to ensure that the assessment incorporates accessible, reliable and diverse information sources, from life sciences to indigenous and local knowledge. Though indigenous and local knowledge refers to forms of knowledge that make the best sense in relation to the social and cultural systems in which they are embedded (Agrawal, 1995), it is also sought out as a source of knowledge that has validity and wide applicability in the world. There are controversies on whether validation by science (Nakashima *et al.*, 2002; Roué *et al.*, 2002; Tsui, 2004; Gratani *et al.*, 2011) is relevant since indigenous and local knowledge and scientific knowledge are based on different philosophies and both make sense in their own systems of reference. However, both systems are to be valued and can be complementary and inform each other. Indigenous and local knowledge is now widely cited in the mainstream scientific literature today and examples abound, in particular regarding vegetation state and dynamics (Lykke, 2000; Wezel *et al.*, 2000; Lykke *et al.*, 2004; Thomas *et al.*, 2004) and deforestation and carbon reduction emissions (Mistry *et al.*, 2016). By highlighting data gaps in both mainstream science and ILK, IPBES will provide opportunities for countries to define appropriate actions and corresponding data and research needs, with links from local to global scales (Faith *et al.*, 2013).

The Africa Regional Assessment makes use of prescribed IPBES methodologies together with a range of bespoke analyses. Results are reported with maps and infographics to aid in the appreciation of complex messages and inter-related data. Each chapter has been developed as a collaborative effort coordinated by the coordinating lead authors and assessment co-chairs, involving lead authors, fellows and invited external contributors. Chapters follow structures agreed at IPBES Plenary sessions and were developed in several iterations to take account of contributions from government and expert independent reviewers, guided by review editors.

Box 1.2: The knowledge, information, and data checklist for IPBES assessments. Source: IPBES (2016a).

1. Consider all sources of knowledge, information, and data (global, regional, and local) – noting that:
    - key global datasets and knowledge products serve a significant role for allowing (sub) regional assessments to replicate and standardize efforts, simplify documentation requirements, and facilitate global synthesis; and
    - regional and subregional assessments may be able to tap into geographically restricted data, information and knowledge products of greater relevance, quality, spatial resolution, accessibility, taxonomic or temporal scope than are available globally.
2. Fully document methodology for selecting knowledge, information, and data to be used in the assessment.
3. All assessments and associated products should be based on knowledge, information, and data that is:
    - fully referenced;
    - sufficiently documented and that adhere to domain-specific meta-data standards; and
    - archived and accessible.
4. Adopt existing knowledge, information, and data and meta-data standards.
5. Knowledge, information, and data quality and confidence should be assessed and reported.
6. Ensure long-term storage and archiving of knowledge, information, and data versions used in the assessment to ensure transparency.

1.2.2 Indicators

IPBES has consulted widely in arriving at a list of 81 indicators for its assessments, including a core list of 30 indicators, of which nine are intended to assess socio-ecological status and trends. Indicators have been selected to cover the conceptual framework comprehensively. Indicators are here defined as data aggregated in a particular manner (quantitative or qualitative) that reflect the status, cause or outcome of an object or process, especially towards targets such as the Aichi Biodiversity Targets or those set by the Sustainable Development Goals (CBD Secretariat, 2014). Indicators can help simplify the enormous complexity of datasets, variables, frameworks and approaches available to IPBES assessments (Müller *et al.*, 2012). They also serve as useful tools for communicating the results of assessments. It is, however, important to recognise the limitations of a given set of indicators in capturing the complexities of the 'real world', since indicators are restricted to what can be measured and for which there are available data. Notably, these limitations are especially significant when it comes to assessing nature's non-material contributions to people and to their quality of life. Indicators are not independent of one another, and relationships between them are non-linear. Moreover, the choices of indicators are related to diverse cultural perspectives. Hence, in IPBES assessments, indicators are subjected to critical analysis and review from a diversity of stakeholders and experts.

1.2.3 Scenarios

Scenarios and models play complementary roles, with scenarios describing possible futures for drivers of change or policy interventions, and models translating those scenarios into projected consequences for nature and nature's contributions to people. In brief, the goals of using scenarios and models are:

- to better understand and synthesize a broad range of observations,
- to alert decision-makers to future impacts,
- to provide decision support for developing adaptive management strategies, and
- to explore the implications of alternative social-ecological development pathways, governance and policy options (Source: IPBES, 2016b).

There are a number of methods and models commonly used for constructing biodiversity scenarios (Pereira *et al.*, 2010; Figure 1.3) and 'forward-looking' approaches (Leadley *et al.*, 2013). These include:

- Expectation (revealing plausible futures) versus desire (defining targets);
- Outlining the future (policymakers) versus fostering anticipatory learning to enable adaptive co-management (local community).

Assessments of status and trends are typically well understood by policymakers and stakeholders because they rely heavily on the analysis of observations. Looking into the future, however, is more complex because it relies on coupling scenarios of future socioeconomic development pathways with models of the impacts of future states of various direct and indirect drivers on biodiversity and ecosystem function and, in turn, nature's contributions to people underpinning human well-being. Assessments of the future of nature and nature's contributions to people are typically explicitly or implicitly built on three main components:

- Scenarios of socio-economic development (e.g., population growth, economic growth, per capita food consumption, greenhouse gas emissions) and policy options (e.g., reducing carbon emissions from deforestation and forest degradation, subsidies for bioenergy, etc.);
- Models projecting changes in direct drivers of biodiversity and ecosystem function (e.g., land-use change, fishing pressure, climate change, invasive alien species, nitrogen deposition, etc.);
- Models assessing the impacts of drivers and changes in biodiversity and ecosystem function on nature's contributions to people (e.g., ecosystem productivity, control of water quantity and quality, carbon storage, cultural values, etc.).

IPBES aims to match its scenarios carefully to the needs of particular policy or decision contexts, paying particular attention to (i) the choice of drivers or policy options that determine the appropriate types of scenarios (e.g., exploratory, target-seeking or policy screening); (ii) the impacts on nature and its contributions to people nature's that are of interest and that determine the types of models of impacts that should be mobilised; (iii) the diverse values that need to be addressed and that determine the appropriate methods for assessing those values; and (iv) the type of policy or decision-making processes that are being supported and that determine the suitability of different assessment or decision-support tools (e.g., multi-criteria analysis and management strategy evaluation).

The regional assessments make use of scenario archetypes—i.e., groups of futures which are deemed 'similar' for the purpose of a specific analysis (Boschetti *et al.*, 2016).

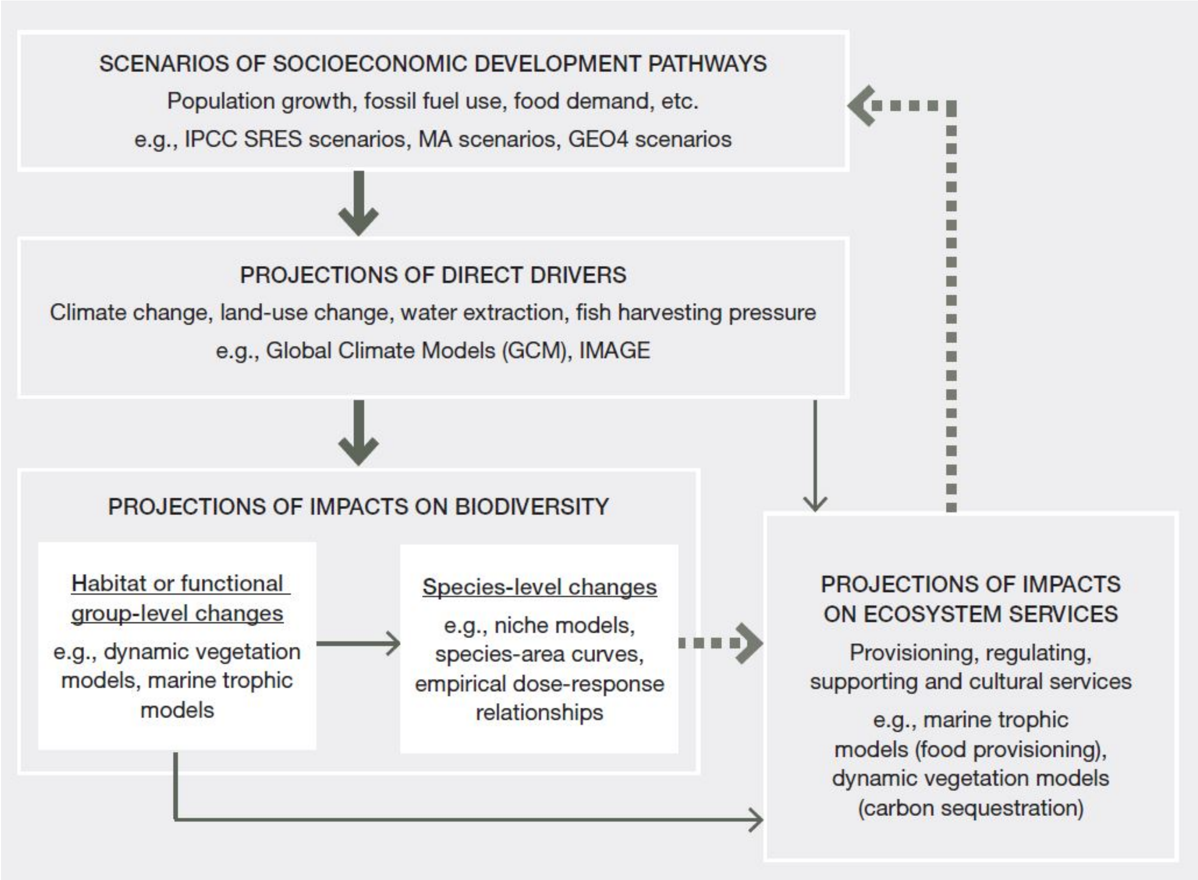


Figure 1.3: Overview of methods and models commonly used for constructing biodiversity scenarios. Source: Pereira *et al.* (2010).

According to current large-scale models and scenarios, in both marine (Cheung *et al.*, 2009; Kaimuddin *et al.*, 2016) and terrestrial (Sekercioglu *et al.*, 2008) realms, climate change has already caused species and biomes poleward/upward/deepward range shifts. This trend is projected to continue and increase throughout the 21st century (Loarie *et al.*, 2009). Extinction rates are also expected to increase (Pimm *et al.*, 1995; Pimm *et al.*, 2014). Modelled projected shifts in the distributions of sub-Saharan Africa's entire breeding avifauna by Hole *et al.* (2009), showed, however, that species turnover across the continent's Important bird area network is likely to vary regionally and will be substantial at many sites. Identifying and protecting these important natural resources under threat from the effects of global climate change will play a key role in mitigating the worst impacts of climate change on biodiversity, as well as helping support human adaptation. The authors of this report emphasise, however, that the protection of these resources will only be achieved if those who live in and depend on these resources are given the power to decide how these resources are managed. Chapter 5 explores this issue further as well as issues related to other drivers and to ecosystem services scenarios (see MA, 2005) for an overview of ecosystem services). Chapter 5 focusses on studies in Africa, and on their implications for human well-being and society, or for future interactions between nature and society using a range of scenario types.

1.2.4 IPBES terrestrial and aquatic units of analysis

The subdivision of the Earth's surface into units for the purpose of analysis is notoriously controversial and there is no single agreed perfect system that IPBES can adopt as its standard. IPBES has consulted widely among the MEP and the experts contributing to the IPBES assessments to arrive at the classification below. This system serves as a framework for comparisons within and between assessments and represents a pragmatic solution, which may evolve as the work of IPBES develops. Note that we describe these as the 'IPBES terrestrial and aquatic units of analysis.' They serve the purposes of IPBES, and are not intended to be prescriptive for other purposes. Note also that the word 'aquatic' is used here to include both marine and freshwater units (Table 1.2).

Table 1.2: The IPBES terrestrial and aquatic units of analysis including some examples for Africa.

UNITS AT GLOBAL LEVEL		UNITS AND EXAMPLES IN THE AFRICA REGION				
		Subregion				
TERRESTRIAL	Type	East Africa & adjacent islands	Southern Africa	Central Africa	North Africa	West Africa
1. Tropical & subtropical dry and humid forests		Afromontane forests (Ethiopia, Kenya, Tanzania & Uganda), Madagascar	Zambia, South Africa	DRC, Congo, Gabon, Cameroon, Equatorial Guinea, Central African Republic		Guinea, Cape Verde Islands
2. Temperate & boreal forests and woodlands						
3. Mediterranean forests, woodlands and scrub					Morocco, Algeria and Tunisia, Atlas Mountain	
4. Tundra and High mountain habitats	High mountain forest	No data	Southern African Great Escarpment and the Cape Fold Mountains	Congo (Ngaliema/ Mount Stanley and Mount Emin), Angola, DRC	North African mountains (Atlas and Rift Mountain)	Niger, Sao Tome & Principe, Senegal, Niger, Gambia
5. Tropical and subtropical savannas and grasslands	Savannas and grasslands	Somalia and Tanzania	South Africa, Zimbabwe	Congo wetlands to Cameroon highlands, Central African Republic, DRC	Morocco, Libya, Algeria, Tunisia, Egypt, Sudan	Burkina Faso, Mali, Niger, Senegal
6. Temperate Grasslands						
7. Drylands and Deserts		Somalia, Madagascar, Eritrean coastal desert	South Africa (Succulent Karoo, Namib desert, Nama Karoo and the Kalahari)	Central African Republic (Chad)	Morocco, Libya, Algeria, Tunisia, Egypt, Sudan	Chad, Mali, Mauritania, Niger, Benin, Gambia, Ghana, Nigeria, Senegal, Sahelian zones
8. Cultivated areas (e.g. cropping, intensive livestock farming)		No data	No data	No data	No specific data	No data
9. Urban/Semi-urban		Dar es Salaam (Tanzania), Addis Ababa (Ethiopia), Nairobi (Kenya), Kampala (Uganda)	Johannesburg (South Africa), Luanda (Angola)	Central African Republic, Kinshasa (Tanzania)	Cairo (Egypt)	Guinea, Nigeria

UNITS AT GLOBAL LEVEL		UNITS AND EXAMPLES IN THE AFRICA REGION				
AQUATIC	Type	Subregion				
		East Africa & adjacent islands	Southern Africa	Central Africa	North Africa	West Africa
10. Wetlands – peatlands, mires and bogs	6. Wetlands	Tanzania, Kenya, Somalia	Mozambique Angola South Africa	Central Congo Basin, Central Africa, Gabon	Morocco, Sudan, Tunisia, Egypt	Senegal River, Niger delta
11. Cryosphere						
12. Aquaculture areas						
13. Inland surface waters and water bodies /freshwater	7. Inland surface waters and water bodies/ freshwater	Lake Victoria, Lake Tanganyika, Malawi, Zambesi River, Jordan River	Zambia and Zimbabwe, South Africa, Botswana	Central African Republic, Equatorial Guinea, DRC	Sudan	Lake Gambia, Lake Volta, Senegal River, Lake Chad, Niger, Mali
14. Shelf ecosystems (neritic and intertidal/ littoral zone)	8. Shelf ecosystems	Madagascar, Tanzania, Zanzibar, Seychelles, Mayotte, Kenya, Somalia	Angola, Tanzania, Mozambique, South Africa	Nigeria, Cameroon, Gabon, Ghana, Congo, Angola	Sudan, Mauritania, Senegal delta and river	Guinea-Bissau and Nigeria, Senegal to the Niger Delta (mangroves), Ghana, Liberia
15. Open ocean pelagic systems	9. Ocean pelagic systems	Kenya, Tanzania, Seychelles	Tanzania, Mozambique, South Africa	Central African Republic	No data	Guinea
16. Deep-Sea	10. Deep-Sea	West Indian Ocean, Eritrea	No data	Congo, Angola	No data	Exists, but no data
17. Coastal areas intensively used by humans						

1.2.5 Addressing data gaps and uncertainties

A range of factors explains why gaps exist in knowledge, information and data (Geijzendorffer *et al.*, 2016; Meyer *et al.*, 2015). In the Africa assessment, data and knowledge gaps are particularly critical due to the considerable size of the informal economy and the weak statistical basis in a number of countries. A few years ago, the World Bank's chief economist for Africa referred to this as "Africa's statistical tragedy" (Devarajan, 2013).

A number of factors have been identified that may provide proxy indicators about the completeness of biodiversity datasets. However, proxies only provide rough approximations, and the completeness of information about biodiversity at different spatial scales must be considered (Soberón *et al.*, 2007). Although there is a strong emphasis on and promotion of peer-reviewed biodiversity data (Costello *et al.*, 2013) to overcome concerns on data quality, there is also a serious limit on the quantity of such published resources for this particular region. In addition, biodiversity and ecosystem services relevant data go well beyond biodiversity data to address a whole range of thematic domains with their own data issues. This serves as a source of uncertainty regarding the data on which to act upon, adding to the inherent uncertainty of complex social-ecological systems in Africa.

The use of rigorous quantitative methods to estimate uncertainty is rarely possible; but, whenever possible, authors have sought to assign confidence terms reflecting the degree of estimated scientific consensus on a particular question. The predictions made in this assessment are based upon a range of different scenarios and wherever possible, outcomes are expressed in terms of ranges, rather than giving precise figures, so that uncertainty may be reflected in an appropriate manner. This should not, however, prevent early action, particularly when different thresholds for critical tipping points have been identified.

Facing the uneven distribution of data and information, this report provides an assessment of gaps and systematically prioritises research to address the gaps associated with each element of the IPBES assessment framework. These are elaborated in the individual chapters and summarised in the executive summary. The knowledge gaps will then help to inform strategic planning of future research activities, including identifying appropriate funding mechanisms and support programmes. From a long-term perspective, an important product of the assessment would be the establishment of an Africa region research agenda that clearly articulates gaps and set priorities for addressing them. This would allow governments, in linkage with the IPBES platform and the wider scientific community to strategically decide where to put more efforts to generate the knowledge base needed for evidence-based development policies fully integrating nature's beneficial contributions to society.

1.2.6 Stakeholder linkages: who will benefit?

Societies, as IPBES guidelines indicate, are faced with threats to long-term human well-being from the loss of biodiversity and degradation of ecosystem services. The global community, in its effort to reverse this trend, has developed a number of conservation and sustainable use strategies of biodiversity commonly referred to as blueprints. Outcomes from the implementation of these blueprints have, in some cases, fallen short of expectations (see Box 1.3 for examples of blueprints).

Box 1.3: Examples of blueprints

Examples at the international level include:

The Strategic Plan for Biodiversity 2011–2020 and its Aichi Targets prepared under the auspices of the Convention on Biological Diversity, the 10-year strategic plan and framework (2008–2018) of the United Nations Convention to Combat Desertification (UNCCD), and the development by the UN General Assembly of the post-2015 Development Agenda and a set of sustainable development goals (SDGs).

Examples at regional and subregional levels include:

The Lake Chad Basin Commission, the Nile Basin Commission, the Central Africa Forest Commission (COMIFAC), etc.

Examples at the national level include:

Forest and environmental management policies and their decrees of application in many countries around Africa.

Examples at the local and community levels:

Not evident

One of the hidden pitfalls of blueprints is their inability to address the uncertainty and surprise that characterises complex social-ecological systems (Gunderson *et al.*, 2002). They cannot, in themselves, fully integrate the interests and dynamic interplay of diverse actors and stakeholders at various scales of significance. A range of participatory approaches and platforms developed over the years need to be mobilised so as to fully involve biodiversity and ecosystem services stakeholders in the design and adaptive implementation of these blueprints. Secondly, to effectively play their roles, some of these stakeholders must be empowered and their capacities strengthened. This will help knowledge flow and co-creation of solutions on the basis of shared understandings. Thirdly, there is a need to recognise where stakeholders might be marginalised and left out of planning and decision-making due to their political leanings, cultural characteristics and levels of education. This is important because stakeholders could be left out of planning and decision-making but not of the actual use or abuse of resources. Fourthly, some of the stakeholder's indigenous and local knowledge systems, particularly in Africa, have large, untapped potential for new ideas and solutions, not only in planning and decision-making but also in the actual process of creating a sustainable, ecologically grounded future.

Given IPBES's commitment to stakeholder engagement, each chapter in this assessment has given due consideration to stakeholder identification, analysis, linkages, mapping and engagement. Such thinking has afforded answers to the questions identified in Box 1.4.

Box 1.4: Consideration of stakeholders in the IPBES Africa regional assessment

Who is a stakeholder?

They are actors, key players (persons or organisations) who have a vested interest in the formulation of policies and the use of biodiversity and ecosystem services for their well-being. These stakeholders or "interested parties" can be grouped into the following categories: international, public, national political, commercial/private, nongovernmental organization /civil society, labour, and users/ consumers just to name a few. On one level, the remit of IPBES means that everyone is a stakeholder, including future generations.

What forms of stakeholder analysis are used?

Stakeholder analysis refers to the systematically gathering and analysing of qualitative information to determine whose interests should be taken into account when developing and/or implementing a policy or program on biodiversity and sustainable use of biodiversity and ecosystem services.

Which stakeholder characteristics need to be analysed?

Characteristics such as knowledge of policies on biodiversity and ecosystem services, interests related to the policy on biodiversity use and well-being, position for or against the policy on sustainable use and biodiversity conservation, potential alliances with other stakeholders, and ability to affect the policy implementation process (through their power and leadership) are analysed.

What are the steps in stakeholder analysis?

The following are the major steps in the process: Planning the process, Selecting and defining a policy, Identifying key stakeholders, adapting the tools, collecting and recording the information, filling in the stakeholder table, analysing the stakeholder table, using the information.

Why is this analysis useful to IPBES?

Knowing who the key actors are, their knowledge, interests, positions, alliances, and importance related to the policy on biodiversity, ecosystem services and sustainable use, allows IPBES to interact more effectively with policy makers, key stakeholders and increase their support for the implementation of given policy options on biodiversity and ecosystem services.

What is stakeholder mapping?

Stakeholder mapping is a collaborative process of research, debate, and discussion that draws from multiple perspectives to determine a key list of stakeholders across the entire stakeholder spectrum. Mapping can be broken down into four phases.

1. Identifying: listing to relevant groups, organizations, and people;
2. Analysing: understanding stakeholder perspectives and interests;
3. Mapping: visualizing relationships and links to objectives and other stakeholders; and
4. Prioritising: ranking stakeholder relevance and identifying issues.

Stakeholder mapping and analysis involves an understanding of key actors and agencies, their networks and capacities, information flows and barriers to action.

The IPBES Africa regional assessment is the first of its kind in Africa. Previously, a subregional assessment was undertaken for southern Africa in the context of the Millennium Ecosystem Assessment. There have, however, been several publications focusing on Africa's biodiversity from the United Nations Environment Programme (UNEP) and a range of other organisations, as well as a report on the State of Biodiversity in Africa, which documents progress on implementation of the Aichi Biodiversity Targets. This assessment will identify key priorities that will help African governments and institutions to develop responses and policy solutions that meet the specific needs of the Africa region as a whole, as well as the five subregions and their national constituents. The knowledge produced has policy implications to assist African efforts to meet the conservation goals set out in the Aichi Biodiversity Targets as well as the Sustainable Development Goals and the African Aspirations for 2063. The knowledge and recommendations produced in this assessment will also be important sources of information for other stakeholders, including the private sector, concerned with the state of biodiversity in Africa and its sustainable future. Interested civil society organisations, such as non-governmental organisations, the media and individuals, may also find the document a useful source of information linking Africa's biodiversity and ecosystem services to human well-being.

1.3 Priority issues in biodiversity and ecosystem services policy and management interventions in Africa

This first assessment of biodiversity and ecosystem services in Africa is taking place at a critical juncture in Africa's history. From a remarkably desolate state at the beginning of the 1990s, Africa began an economic recovery at the end of that decade. By 2010, albeit with important differences between countries, it had become the second fastest growing economy and a prime destination for Foreign Direct Investments and other financial flows. The latter include remittances that now surpass foreign aid to the region (Bodomo, 2013). Such growth has been widespread across sectors, including in services, natural resources, and agriculture (Roxburgh *et al.*, 2010). At the same time, Africa was considered the only region that emerged from the Millennium Development Goals with increasing extreme poverty (Asongu, 2015; World Bank, 2016). In 2010, half of its population was living under the extreme poverty line of $1.25 per day (UN, 2013). The related conclusions are, however, contested by certain recent studies. These studies estimate that during the Millennium Development Goals period, Africa actually reduced its income inequality and its poverty (Pinkovskiy *et al.*, 2014) and outperformed the world average of 39% with respect to reducing the proportion of the population with incomes below $1 a day (Fukuda-Parr *et al.*, 2013). This controversy and related observations underscore Africa's current scientific and development challenges, including the critical role that dynamic knowledge of biodiversity and ecosystem services must play in overcoming them.

As mentioned earlier, Africa has abundant biodiversity, arable land, and richly diversified ecosystems. These serve as essential building blocks of sustainable development. African countries are, in general, matching the global trends in achieving Aichi Biodiversity Targets (UNEP-WCMC, 2016). This is despite the fact that there is an ongoing loss of biodiversity in Africa due to anthropogenic factors in addition to the negative impact of climate change that intensifies the impact of pressures. It is reported to the Convention on Biological Diversity that over 80% of African countries have made progress towards Aichi Biodiversity Target 17, i.e., updating their National Biodiversity and Strategic Action Plans. There is, however, a need to transfer the National Biodiversity Strategies and Action Plans into actions and use them as policy instruments (see Chapter 6). There is also a lack of consistent biodiversity indicators to evaluate conservation requirements and progress in National Biodiversity Strategies and Action Plans, a situation which is, in part, related to financial constraints.

Looking forward, this assessment thus takes into account the essential need for African policymakers to gain first-rate understanding of biodiversity and ecosystem services and, thus, to fully integrate them as assets into Africa's growth and transformation plans. Biodiversity and ecosystem services and policies should thus mutually affect each other in a way that ensures the creation of more benefits and fewer losses now and for future generations. To sustain its growth under conditions of climate change and increased pressure on natural resources, the continent needs to better understand and harness its biodiversity and ecosystem services potential in order to innovatively meet the demand of its population and nascent industries. In turn, the growth and transformation paths that it chooses will affect biodiversity and ecosystem services trends under different future scenarios, which will be discussed in Chapters 4 and 5 (see also SPM sections B and D). Africa has not yet achieved its structural transformation; thus, the direction and forms of this impact remain uncertain due to sharply contrasting predictions of future economic development. Important differences are also emerging within countries, between countries, groups of countries and regional blocs (Diaw, 2014), which may lead to diverse configurations of biodiversity and ecosystem services and economic development across the continent.

This section presents an overarching description and an initial assessment of the priority issues concerning biodiversity and ecosystem services in Africa. They are organised into nine clusters of thematic foci previously outlined by the scoping document for the Africa Regional Assessment (IPBES_3_6_Add.2):

- The first three—gender, indigenous and local knowledge, and climate change (1.3.1 to 1.3.3)—are cross-cutting themes that are relevant to most, if not all, the other themes discussed in the section.
- This is followed (in 1.3.4) by a presentation on food, water and energy as a nexus of interrelated biodiversity and ecosystem services issues. All are tightly linked to agriculture, as well as agro-pastoral and renewable natural resource domains, such as forestry, agroforestry and fisheries. All are critically important to biodiversity and ecosystem services. Key thematic foci concerning invasive species (1.3.5) and marine and terrestrial habitats degradation and restoration (1.3.6) complete the presentation of this central node of questions for livelihoods and environmental health in Africa.
- Population, poverty and health (in 1.3.7) is the fourth major cluster of issues that the section addresses in a way that emphasises their interrelations both as causal factors and partial outcomes of environmental health and environmental processes.
- Essential to the present state and to the future of biodiversity and ecosystem services, tenure and governance are then presented, in order to provide preliminary insights into the policy and management interventions that will be required in the context of this assessment and in relation to issues of peace, security and trade (1.3.8)
- This review of issues ends (1.3.9) with an overview of sustainable use challenges in a context of transition toward green-blue models of economic development more reliant on nature and on the many goods, services and wider beneficial contributions that can be drawn from it.

Figure 1.4, below, graphically illustrates this broad articulation of thematic issues. It is an indicative rather than exhaustive figure, solely meant to set the scene and guide the reader through the complex set of themes and interactions addressed in the section. These elements should be viewed separately with their interrelations and cross-sector connections. They are addressed in more detail from Chapter 2 through to Chapter 6, in this assessment.

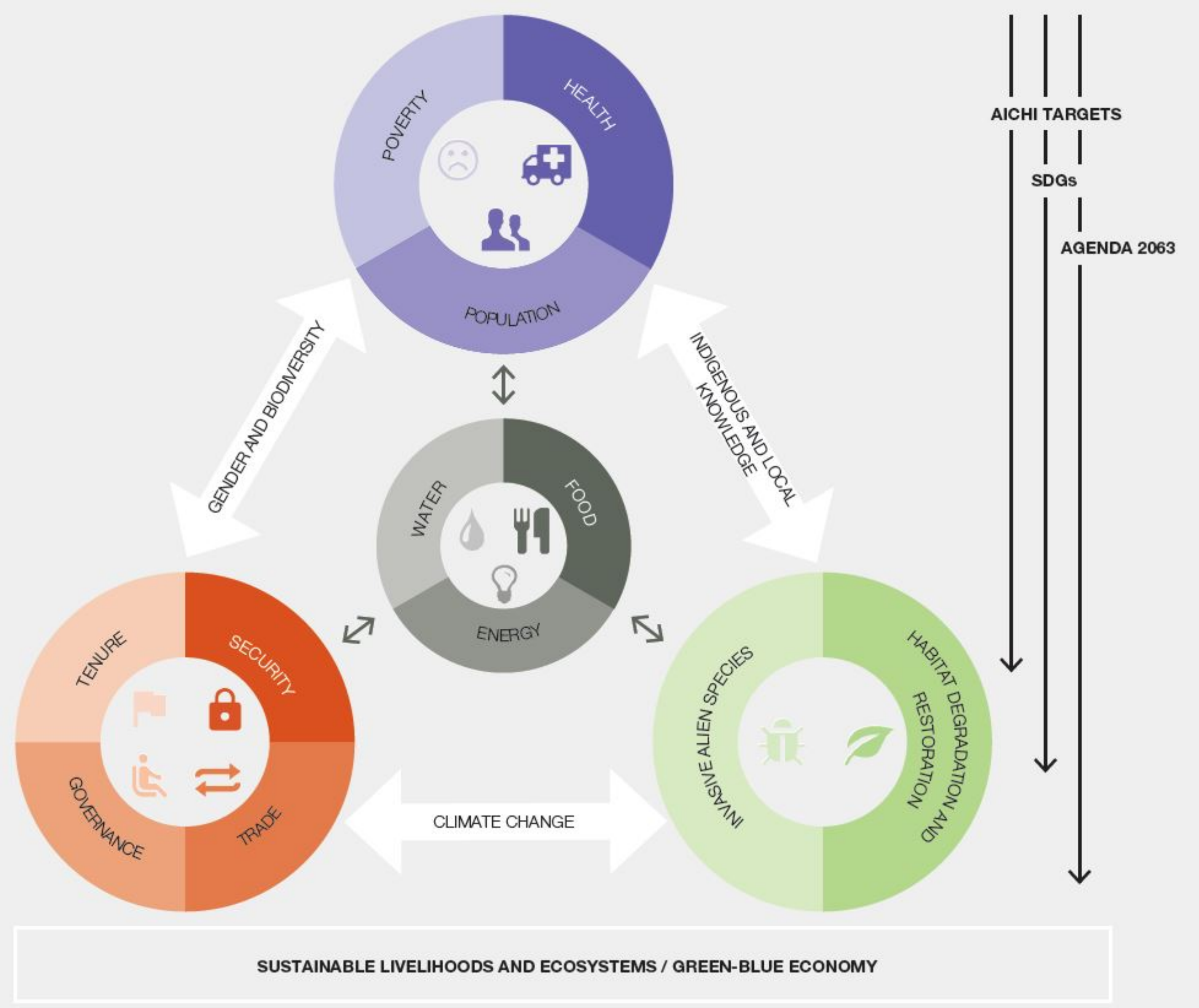


Figure 1.4: Nature's contributions to people in Africa is related to complex social-ecological, economic and political challenges that are interrelated and, at times, nested into each other. Things happening in one area of policy have repercussions on, or implications for, other areas. This is why each of the illustrated issues can potentially be considered both as entry points for, and outcomes of public policies. For instance, interrelated water, food and energy issues are influenced by, and impact on, population, poverty, and health, which in turn show mutual influences with governance, trade and tenure. In part of Africa, problems related for instance, to land tenure and access to natural resources are known to have spilled into grave problems of peace and security, severely affecting biodiversity and ecosystem services to people. This is amplified by climate change that impacts all of these factors and future economic options. Indigenous and local knowledge and the role of women and gender relations have proved to be essential to understanding these interrelated challenges and to addressing them positively. These roles and mutual influences will be essential to the development of sustainable trajectories for livelihoods and ecosystems and to ecological gains in the social transformation of the African economy, an underlying goal of Africa's major international commitments, including Agenda 2063, the SDGs and the Aichi biodiversity targets.

1.3.1 Gender and biodiversity

Biodiversity, as indicated earlier, represents a cornerstone for many indigenous and local communities, in particular women and vulnerable groups. It can provide them with multiple benefits, can support their needs, work, value systems, and is a potential asset in their economic future. Direct connection with land is an essential concern for indigenous and local communities who, for centuries, have collected firewood and other bush products for food, medicine, cosmetic use and building material. Natural resources play a key role in enhancing many communities' livelihood and subsistence (UNEP, 1999).

In order to fully understand the interactions of people with biodiversity and ecosystems services in Africa, these must be seen through the lens of gender, culture and social relations, while at the same time considering the social roles and power relations between both men and women. Gender analysts have reiterated the fact that men and women often manage, utilise and organise natural and agricultural resources differently, with consequent impacts on biodiversity and ecosystem services and the management thereof in Africa.

Women have developed a distinctive relationship with biodiversity and they often play the predominant role as users and guardians of biodiversity—as plant collectors, family gardeners, plant domesticators, herbalists and seed guardians. For example, in Sierra Leone, women were found to be able to name nearly four times as many uses of trees compared to men (Sasvari *et al.*, 2010).

1.3.2 Indigenous and Local Knowledge (ILK)

Indigenous and local knowledge and practices (ILKP) systems are considered by IPBES to be dynamic bodies of social-ecological knowledge, practices and beliefs about the relationship of living beings, including humans, with one another and with their environment. ILKP is highly diverse, produced in a collective manner and reproduced at the interface between the diversity of ecosystems and human cultural systems. It is continuously evolving through the interaction of experiences and different types of knowledge (written, oral, tacit, practical, and scientific) among indigenous peoples and local communities. IPBES is developing guidance for the integration of ILKP into its assessments that respects not only the diversity and value of ILKP, but also the rights of indigenous and local communities to share in the benefits of knowledge gained from the assessments. IPBES integrates ILKP into its assessments through the appointment of experts to conduct and review assessments (Annex to IPBES/4/7).

The value of ILK is becoming recognised by scientists and policymakers, and is an evolving subject in national and international law (Mauro *et al.*, 2000 in Abdel Rahman, 2009). The UN and similar agencies have acknowledged the rights of indigenous people to be recognised and the right of their knowledge to be respected as any other form of knowledge, including scientific knowledge (Abdel Rahman, 2009). The potential contribution of ILK in traditional ecological knowledge and social-ecological studies has gained growing attention in the context of accelerated global change and generalized ecosystem service decline. Scholars assert that indigenous and local cultures are not adequately analysed, and yet they are more environmentally embedded than knowledge in modern society (Gómez-Baggethun *et al.*, 2013). ILK's role has been highlighted by the CBD in article 8(j), section 1.3.5. "*where it states that all parties subject to national legislation, shall respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity, all relevant parties shall promote ILK's wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge innovations and practices*" (UN, 1992). Indigenous knowledge systems are based on cognitive understandings and interpretations of the social and physical/spiritual world (Dei, 2000).

"Indigenous people and their communities represent a significant percentage of the global population. They have developed over many generations a holistic traditional scientific knowledge of their land, natural resources and environments"

(UNCED, 1992)

Despite the fact that ILK is relatively new to climate science, it has long been known as a major basis of perception and information in various fields such as agroforestry, traditional medicine, biodiversity conservation, customary resource management, impact assessment and natural disaster preparedness and response (Raygorodetsky, 2011). Indigenous/local people, who have developed rich knowledge over the centuries, could be negatively influenced by other modern cultures if this traditional knowledge disappears (World Bank, 1998). This will also negatively affect sustainable development prospects in Africa.

1.3.3 Climate change

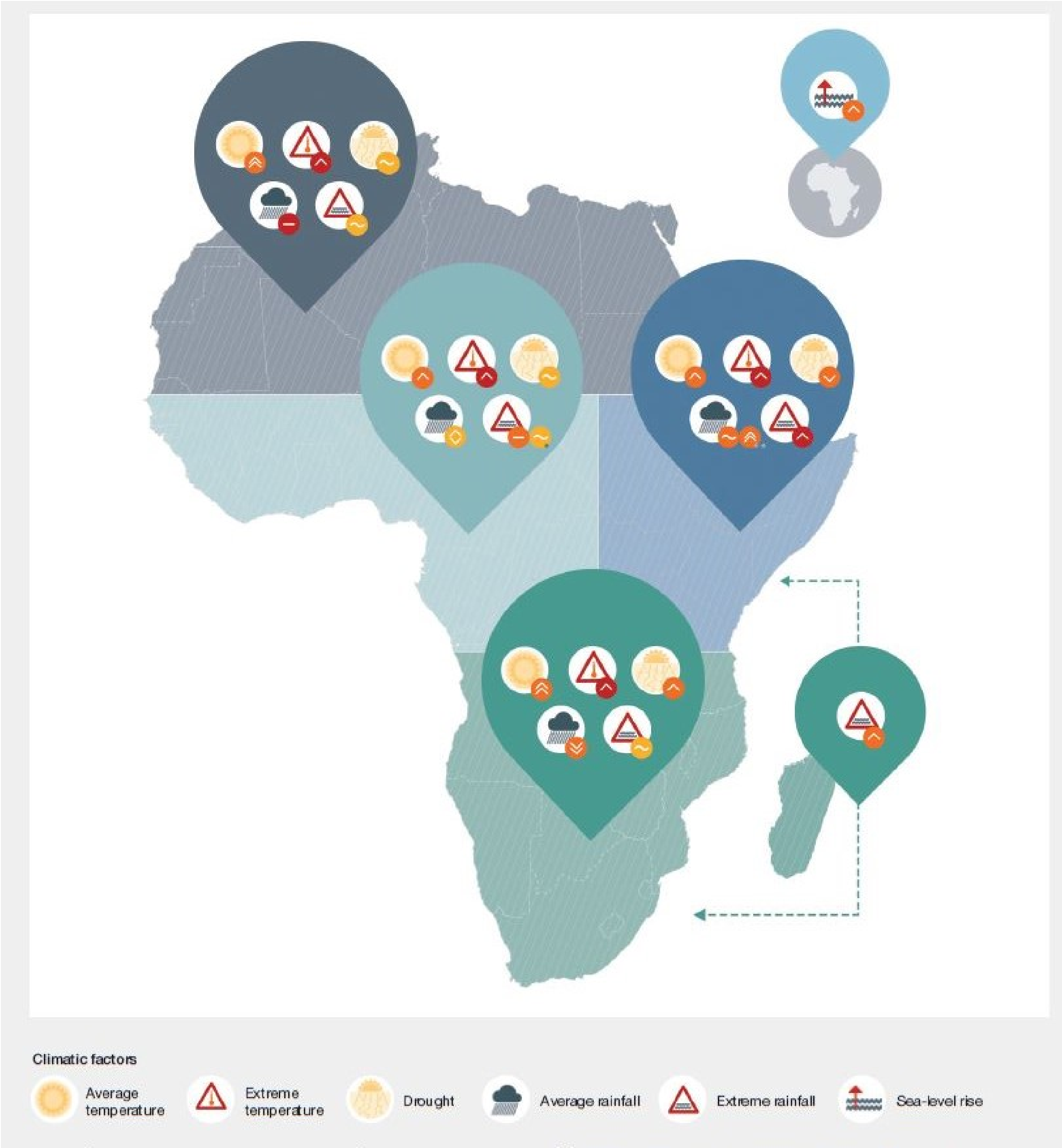
In his foreword to the "Guidebook - Addressing Climate Change Challenges in Africa: A Practical Guide towards Sustainable Development" (AMCEN, 2011), Sangare, highlighted that *"There is a consensus among scientists, policy makers and development practitioners that climate change poses complex challenges to the development of countries in Africa"*. Recent scientific information published since the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report confirms that the world is on course for levels of warming that will be catastrophic, especially for Africa, where these impacts are combined with "poverty, poor policy and institutional framework". West Africa, and particularly Sahel and the Horn of Africa would be particularly affected by desertification and droughts linked to climate change (Beg *et al*., 2002; Gan *et al.*, 2016), despite the overall re-greening of the Sahel that was observed by remote sensing since the drought of the 1980s (Hiernaux *et al.*, 2016). Along the northern coast of Africa, changing climate conditions and accelerating sea level rise will intensify the stress on many coastal zones, coastal cities, lagoons, wetlands and deltas (El-Nahry *et al.*, 2009; Kilroy, 2015) (see Chapter 4, section 4.2.2.2).

The IPCC 5th Assessment report confirmed that climate change serves as the ultimate threat multiplier to the pressures already experienced by various sectors, and is likely to have widespread impacts on human and natural systems (IPCC, 2014). Major challenges affecting ecosystems on the African continent, based upon the IPCC report, were summarised by the Climate and Development Knowledge Network (CDKN, 2014), and are illustrated in Figures 1.5 and 1.6.

Climate change affects virtually all the priority issues addressed in this section (see also Chapter 4, section 4.2.2.2). This, of course, includes the critical sector of water. For example, as mentioned with regard to the Nile river basin in the following subsection, the struggle to control dwindling water resources can lead to conflict. The challenge will be to provide water resources for future populations and manage climate and water-related diseases, land degradation, crop failures and diminished yields and their impact on food security, energy and livelihoods. Poverty and human well-being may be substantially affected. Poverty is, of course, a central issue in terms of how climate change affects both people and ecosystems by restricting adaptive capacity and enhancing vulnerability over the longer term. Humans, animals and plants may be pushed out of water-stressed areas and thus become displaced (see Chapter 4). Where people cannot move, they are forced to cope however they can. The adverse effects of climate change in Africa may include (but are not limited to) reduced crop production and diversity, regime shifts in the African ecosystem, worsening of food security, the increased incidence of flooding and droughts, spreading disease and an increased risk of conflict over scarce land and water resources (World Bank, 2012a). Climate change impacts are transmitted through a complex array of mechanisms. The effects on individual countries and cross-countries ecological zones are mediated by specific social, economic and environmental circumstances.

It is important to note, however, that there are also indigenous strategies for resource management, which should, with the right support, play an important role in adaptation. A critical role for this Assessment, as well as the IPBES process, is to help identify such strategies and to enable knowledge exchanges between different communities; and well as considering circumstances under which such strategies may be best enabled and supported. People's adaptive practices may also be informative as to what changes are taking place and how biodiversity and ecosystem services are affected (see, for example, the IPBES Assessment Report on Pollinators, Pollination and Food Production; IPBES, 2016c). Climate change may also, under certain circumstances, be beneficial and present opportunities—and such opportunities require identification. Indigenous and local communities, whose livelihoods highly depend on environmental conditions, have developed detailed knowledge of climate phenomena and influences through repeated observations transmitted over generations. This allowed them to develop adaptive strategies to deal with climate variation and risk (Gemedo-Dalle *et al.*, 2006). Many communities have already recognised the effects of climate change and their current livelihood strategies are increasingly climate independent (Nielsen *et al.*, 2010a, 2010b). For thousands of African farmers, who are abandoning farming and leaving rural areas because of low yields due to increasing droughts, the tipping point for climate change adaptation may already have passed.

Figure 1.5: The IPCC 5th Assessment Report summary of impacts of climate change in Africa. Sources: CDKN (2014); IPCC (2014).



SYMBOL	RAINFALL	TEMPERATURE	EXTREME RAINFALL, EXTREME TEMPERATURE, SEA-LEVEL RISE
	up to 30% increasing trend	1-6°C increasing trend	–
	up to 10% increasing trend	1-4.5°C increasing trend	increasing trend
	both increasing and decreasing trends	–	both increasing and decreasing trends
	up to 10% decreasing trend	–	decreasing trend
	up to 30% decreasing trend	–	–
	inconsistent trend	inconsistent trend	inconsistent trend
	no or only slight change	inconsistent trend	inconsistent trend

Levels of confidence in findings

High confidence Medium confidence Low confidence

Figure 1.6: The IPCC 5th Assessment Report summary of future climate trends for Africa. Sources: CDKN (2014); IPCC (2014).

1.3.4 The Food, Water and Energy Nexus

Africa's increasing population (see 1.3.7) is leading to a growing demand for, and consumption of natural resources, collectively resulting in land-use change as agricultural expansion into natural habitats takes place. What makes the situation all the more paradoxical is that Africa is also a major supplier of food to the rest of the world. While the demand for food, water and energy is steadily growing, the resources required to meet it are, in a number of cases, dwindling (Rockström *et al.*, 2009; State of the Planet Declaration, 2012). The interdependencies amongst water, food and energy—represented by the food-water-energy nexus concept (Hoff, 2011; Hussey *et al.*, 2012; Marsh *et al.*, 2007)—are numerous and complex. The following sections provide an overview of some of these in terms of how they affect biodiversity and ecosystem contributions in the context of Africa.

1.3.4.1 Meeting Africa's demand for food: Agriculture and African food systems

Africa arable land is estimated at 8.07 million km^2 (27% of Africa's landmass), of which only about 1.97 million km^2 is under cultivation (UNEP, 2016). This amounts to around 60% of the world's uncultivated arable land (Roxburgh et al., 2010; APP, 2014). Yet, its agriculture does not presently feed all the population and it has to resort to increasing food imports. According to the Africa Progress Report (APP, 2014), the region, which used to be a net exporter of food in the 1990s, now foots an import bill worth $35 billion per year for rice alone. As a whole, sub-Saharan Africa today exports less than Thailand, and the continent exploits less than 1.5% of the 240 million hectares suitable for rice cultivation. In addition, Africa makes less use of improved seeds and fertilisers than any other region, and its soils are literally mined as a result: "An estimated 8 million tons of nutrients are depleted every year in Africa" (APP, 2014). As indicated earlier, African agriculture has faced multiple challenges, ranging from low productivity to poor or non-existent markets and infrastructure. There has been a decline in the production of major cereal crops over the past four years, which has been attributed to low input usage, declining soil fertility, erratic climatic conditions and low government funding of development efforts in the sector. A key question, therefore (amongst others), is how Africa is going to address these issues of soil fertility and productivity of its agriculture in the coming years (the timeframe of the Sustainable Development Goals).

Biotechnology, in the form of genetically modified crops, was advanced for years as a possible response to low agricultural productivity in Africa. It is claimed, for instance, that since Bt-maize was introduced into South Africa in 2003, it has reduced losses of maize incurred through damage by stem borers. Bt-maize is corn that is genetically modified to express one or more proteins from *Bacillus thuringiensis*, a soil bacterium; protein poisonous to certain insect pests. Genetically modified organisms, however, face much opposition. Key among the perceived threats are the incomplete local knowledge and control of the technology, the loss of food sovereignty through proprietary technology of multinational corporations, and the potential for irreparable damage to African indigenous seeds (African Centre for Biodiversity, 2017). For example, Burkina Faso's recent decision in early 2016 to completely phase out production of Monsanto's genetically modified Bt cotton was caused by the deterioration of the quality of its cotton and is likely to become a case study in the genetic modification policy debate in Africa. Burkina Faso was a top world producer of high-quality cotton in 2003, when it started experimenting with Bt cotton. Monsanto's genetically modified cotton seed was producing higher yields and had passed all field trials. The transgenic seed was launched on a large scale in 2007 and, within two years, had taken over 80% of the country's cotton crop, with tens of thousands of people economically dependent on its production. The economic boom was, however, short-lived. With a deteriorating quality, the country's cotton ceased to be economically viable in the marketplace, which led to the reversal of Burkina Faso's genetically modified organisms' policy.

Other approaches do exist and can help tackle the dual challenge of productivity and ecology in Africa. Agriculture captures more than 70% of all water used globally (WWAP, 2016) and further affects the water sector through land degradation, changes in runoff, and disruption of groundwater discharge (Alauddin *et al.*, 2008). Sustainable agricultural management based on indigenous local knowledge (ILK) and local practices, and interventions designed to prevent land degradation and to save water and energy are thus particularly important. These can help increase groundwater recharge and water storage in the soil, as well as reduce the use of energy-intensive fertilisers. Ecological intensification of agriculture, which relies solely on natural processes, including biomass, indigenous microorganisms and symbiotic microorganisms, is another alternative to chemical fertilisers and pesticides, which are known for their long-term negative impacts on soil biodiversity, environment, and human health (Matson *et al.*, 1997; FAO, 2007a; Barreiro-Hurlé, 2012).

Bio-fertilisers based on such natural processes have been successfully tested in West and Central Africa (Sene *et al.*, 2012; Ngonkeu *et al.*, 2013), although their considerable market potential is still largely unknown and underdeveloped on the continent. This ecological smart agriculture has been associated with eco-agriculture and large-scale approaches such as Integrated Landscape Management (ILM). ILM is an increasingly popular set of approaches that seek to address complex people-food-climate-biodiversity and ecosystem issues in an integrated manner and through long-term cooperation of land managers and stakeholders (LPFN, 2015).

Closely linked to, and sometimes in competition with agriculture, extensive pastoral production is practised on 25% of the global land area, from the drylands of Africa (66% of the total continental land area) and the Arabian Peninsula to the highlands of Asia and Latin America. It provides 10% of the world's meat production and supports some 200 million pastoral households who raise nearly 1 billion head of camel, cattle and smaller livestock, about a third of which are found in sub-Saharan Africa.

Statistics from the African Union's policy framework for pastoralism show that there are 268 million pastoralists. They live and move on 43% of Africa's landmass, and contribute between 10 and 44 % of the GDP in the countries where they reside (AU, 2010). Pastoralism is faced with important challenges related to population growth and the resulting shrinking and fragmentation of land; related conflicts over resources; security of pastoral livestock assets; climate change; as well as food price increases and financial crises. However, its potential for reducing poverty; generating economic growth; managing the environment; promoting sustainable development; and building climate resilience, is considerable. A study by the International Institute for Environment and Development (Hesse, 2014) shows that pastoralists who feed their animals solely on natural dryland pastures can achieve rates of productivity as high as on modern farms. Pastoralism has such potential because it relies on ILK built through generations of practice and living in specific environments. Pastoralism has been a livelihood in many areas for millennia and, through these practices, has contributed to shaping present ecosystems (see for example Gemedo-Dalle *et al.*, 2005, on Borana pastoralists).

1.3.4.1.1 Forest and agroforestry systems

Forests in Africa are major providers of food and energy on the continent, and they play a crucial role in conserving biodiversity, mitigating climate and maintaining functional ecosystems. Africa is home to 17% of the world's natural forests (675 million hectares), yet, it makes only contributes 2.8% of the value-add of forests globally (FAO, 2014a). The Congo Basin, the second largest contiguous block of tropical rainforest, also contains tropical dry forests, representing nearly a third of Africa's natural forest areas. In addition, the continent contains 31% of the world's 'other wooded lands'. This represents a combined area of 350 million ha of savanna where "scattered tree growth is too sparse to be defined as forest but where the ecological and socioeconomic functions of trees are nonetheless important" (FAO, 2011).

Within these forested landscapes are also found agroforestry systems—that is, land-use management systems in which trees or shrubs are grown around or among crops or pastureland. Agroforestry lands are the most widespread agricultural system in sub-Saharan Africa (Boffa, 2000; Garrity 2010). They include semi-domestic woody species of trees and shrubs that are neither planted nor cultivated but are vitally important. A remarkable example is the commonly known shea tree (karité in French), *Vitellaria paradoxa*, probably the most economically and culturally important tree species in all the Sudanian belt (Boffa, 2015). That region is the sole supplier of shea to the growing international market fuelled by the chocolate and cosmetic industries; although shea is still produced and processed by smallholder farmers and entrepreneurs, many of them women.

The International Standard Industrial Classification of All Economic activities, revised and published by the UN Statistics Division, subsume forestry and fishing under agriculture and considers natural 'resources' only within the frame of extractive industries (mining and quarrying). That standard classification has sometimes hidden the potential and structural transformation needs of African forests. Currently, Africa is gaining limited economic benefits from its forests, while, this natural capital is being depleted by deforestation, large-scale land acquisitions and extensive infrastructure developments (Nelson *et al.*, 2006).

The majority of African populations (62.7% in sub-Saharan Africa, and 46.3% in North Africa in 2010) still live in rural areas (World Bank, 2012a). They are highly dependent on natural resources including fish, agroforestry, and forest products for their livelihoods. There are many cases across Africa that have demonstrated the role these resources play in providing various economic and social benefits, including improved dietary nutrition outcomes and economic and nutritional well-being (Brashares *et al.*, 2011; Golden *et al.*, 2011; Johnson *et al.*, 2013; Ickowitz *et al.*, 2014; Fa *et al.*, 2015; Rowland *et al.*, 2015). Promoting and restoring agro-forest landscapes and increasing forest cover (and the wild foods stored within) should be emphasised for the protection of biodiversity as well as livelihood security.

Most importantly, Africa is the only region that derives most of its forest timber value (65%) from primary forestry activities, such as logging and fuelwood collection. Other regions contribute 75% or more of their economic forestry value from high-value processing activities (Diaw, 2014; FAO, 2014a). In addition, Africa has a large and extraordinarily diversified pool of non-timber forest products (NTFPs). Unfortunately, African NTFPs value chains, though essential to the income and livelihood of millions of Africans and, indeed, to their very history and culture, are still vastly underreported and misunderstood (Diaw, 2015). Currently, the global income from NTFPs is estimated to be around $88 billion (FAO, 2014a), with Africa representing just 6% of the total. But those estimates are not only underestimated, they are also uniquely based on primary NTFPs production, ignoring the considerable potential for downstream NTFPs processing and value addition in food, beverage, additives, nutraceutical, cosmetic and aromatic value chains. Paradoxically, this also reduces the agriculture and market diversification possibilities that would come with domestication and commercialisation of agroforest species taken from the wild to sustain the new industries.

1.3.4.1.2 Marine fisheries

African waters are reputed for the abundance of their fishery resources. The different sectors operating throughout Africa target 643 taxonomic groups. Over 280 taxa are exploited in the Mediterranean coast of Africa alone, with a clear dominance of small pelagic species such as sardines (*Sardina pilchardus*, Least Concern), sardinellas (*Sardinella* spp.) and anchovies (*Engraulis encrasicolus*, Least Concern) (37%) (Belhabib *et al.*, 2016). Three of the 6 large marine ecosystems (LMEs) of Africa rank within the first four most productive LMEs in the world, with the Canary Current, the Benguela Current and the Somali Coastal current ranking 2nd, 3rd and 4th globally (Rosenberg *et al.*, 2014). Not surprisingly, the fisheries of Africa provide a source of livelihood for 8 million active fishers and their families (Teh *et al.*, 2013; Belhabib *et al.*, 2015a). If all catches were landed in Africa, African fisheries could contribute a landed value of $20 billion to national economies (Belhabib *et al.*, 2016), with an additional $3.6 billion injected by the small-scale fishing sectors across the value chain (Dyck *et al.*, 2010). Overall, in Africa, industrial fisheries are almost exclusively operated and controlled by foreign interests and their catches are rarely recorded. Monitoring efforts for the artisanal sector vary from good (based on comprehensive surveys) to non-existent. Subsistence and recreational fisheries are not monitored and in many cases, are simply assumed to be marginal. The artisanal sector, whose landed value reached $4 billion in 2010, is in decline since 2004 along with the industrial sector's catch, despite an increasing fishing effort. Illegal fishing and intense under-reporting (52%) of the total catch are exacerbated by the lack of governance, high corruption, and little transparency on fishing agreements (Belhabib *et al.*, 2015b). However, positive patterns can be observed in community-based management successes, particularly through an increasing network of Marine Protected Areas, which currently covers 22% of Africa's inshore areas, as well as initiatives to combat illegal fishing such as Fish-i Africa (https://nfds.info/experience/fish-i-africa/) and Oceans Beyond Piracy (https://oceansbeyondpiracy.org/). In addition, aid that focuses on policy development should work hand in hand with communities to integrate all dimensions of traditional knowledge and management techniques. The 'South West Indian Ocean Fisheries Governance and Shared Growth Project' is implementing this strategy in several African countries (Tanzania, Zanzibar, Mauritius, Madagascar, Seychelles) in the South Western Indian Ocean, supported by the World Bank with $150 million based on the economy of high value local fisheries (World Bank, 2015b).

Unsustainable practices such as by-catch discarding are responsible for around 20% of catch loss. Catch rate declines (Belhabib *et al.*, 2012) indicate unsustainable levels of fishing. Indeed, of the 14 most targeted fish stocks, 10 are fully or overfished, including stocks of sardines, anchovies and other small pelagics (FAO, 2015). Increasing fishing subsidies and the effects of the Arab spring have impacted on fisheries as illegal fishing increased, particularly by boats from the EU and Korea targeting tunas and billfishes (Belhabib *et al.*, 2012). Many countries have also been affected by coup d'états, civil wars, and, more recently, epidemic outbreaks, which leaves the region highly exposed to illegal fishing, and constrains small-scale fisheries to grow in size and expand their geographic and time ranges (Belhabib *et al.*, 2015c). Increasing fishing range, and hence fuel usage has contributed to increasing fishing costs and deepening the poverty trench. For instance, 143,000 artisanal fishers in the Canary Current LME find themselves with an average daily income of $13 (Belhabib *et al.*, 2015b). The same pattern is observed in the Guinea Current Large Marine Ecosystem with an even higher poverty rate within fishing communities and a daily income of $6.1 on average for over 610,000 artisanal fishers (Belhabib *et al.*, 2015b). In South Africa alone, some 700,000 recreational fishers target over 200 species and caught 5,200 tons in 2010 (Le Manach *et al.*, 2015), which is the equivalent of $79 million. Despite improved reporting in Madagascar, over-exploitation and illegal fishing fleets that catch over 70,000 tons per year threaten the livelihood of some 120,000 Malagasy small-scale fishers (Le Manach, *et al.*, 2012), a trend that is similar to their counterparts in West Africa (Belhabib *et al.*, 2015b). Similarly, small-scale artisanal and subsistence fisheries in Comoros (80% of the total catch), also noted a major decline in fish abundance and size (Le Manach *et al.*, 2015).

In 2011, the contribution of inland and marine fisheries to national and agriculture Gross Domestic Products (GDPs) and the employment generated was estimated at more than $24 billion, 1.26% of the GDP of all African countries. It includes marine capture fisheries, post-harvest, licensing of local fleets, and aquaculture. (De Graaf *et al.*, 2014). According to data presented in The State of World Aquaculture and Fisheries 2014 (FAO, 2014b), in 2014 there were about 5.9 million fishers and fish farmers in Africa (Table 1.3) but this figure does not include employment in post-harvest activities.

Table 1.3: Number of fishers and fish farms in Africa (in thousands). Sources: FAO (2014b, 2016).

	2000	2005	2010	2011	2012	2013	2014
Fishers	4084	4290	4796	4993	5587	6009	5674
Fish Farmers	91	140	231	257	298	279	284
Total	4175	4430	5027	5250	5885	6288	5958

1.3.4.1.3 Freshwater fisheries

People living in rural inland fishing communities are often among the most vulnerable in developing countries. The classic view of a fishery—including the fish resource and harvest systems—brings discussion about improving well-being in these communities directly to issues of reducing fishing pressure or harmful fishing practices, to managing resources in a way that promotes sustainable use (WorldFish Center, 2010). Household vulnerability analysis in fishing communities in Nigeria and Mali revealed that, despite fishing being the primary livelihood, vulnerabilities related directly to the state of the fishery resource were ranked lower than those related to basic human needs, predominantly food insecurity and lack of access to health, education and credit services (WorldFish Center, 2010).

The inland fisheries of the East Africa Community (EAC) Partner States of Kenya, Tanzania and Uganda are based predominantly on its major freshwater lakes, the most notable being Lake Victoria, the world’s second largest freshwater lake with an area of 68,800 km^2 (Scullion, 2007). Inland fisheries contribute between 2–12% of the GDP in each country and produce fish for domestic and export markets (Scullion, 2007). The value of the catch from Lake Victoria alone is estimated at $350 million at landing sites with a further $250 million generated by the export of Nile perch (Scullion, 2007). Other dominant fish species include Nile tilapia, a small indigenous cyprinid (*Rastrineobola argentea*, Least Concern), as well as various types of catfish. These lake fisheries support the livelihoods of over 3 million people in directly dependent households by providing employment, income and high-quality food in the form of nutrients and animal protein for millions of consumers in the region (Scullion, 2007). The transition from a centralised to participatory management approach has involved many different initiatives in East Africa in recent years, most of which have been small-scale and a few large-scale. The implementation of a system of co-management for inland fisheries in the East Africa Community aims to provide direct benefits for men and women fisheries resource users and their families who are dependent on fisheries for their livelihoods.

1.3.4.2 Water in Africa

Water is vital for all life on Earth and therefore is one of nature's most important contributions to people. It is connected to the major sectors driving African economies, e.g., the urban, industrial and service sectors, and particularly agriculture and energy (see 1.3.4.1, 1.3.4.3; Molden *et al.*, 2007; Hellegers *et* *al.*, 2008). It is also critical to population, health and poverty, as discussed in 1.3.7 and in Chapter 4. Sub-Saharan Africa is a region with a high number of transboundary river basins. Sixty-three of the world's 261 international river basins are located on the African continent. But, as a whole, Africa is also the driest continent after Australia (Naik, 2017). This has significant economic, environmental and policy implications.

As pointed out by the Africa Water Vision 2025 (UN-Water/Africa, 2004), Africa has “highly inadequate access to basic water supply and sanitation services in Africa”. About 65% of the population in rural Africa did not have access to an adequate supply of water and 73% were without access to adequate sanitation in the early 2000’s. Despite the global progress made during the Millennium Development Goals, Africa, with the exception of North Africa, still faces uniquely severe water and sanitary conditions as maps in figures 1.7 and 1.8 illustrate. Only 28% of the sub-Saharan population had access to basic sanitary conditions in 2015, and more than 40% did not have access to safe drinking water.

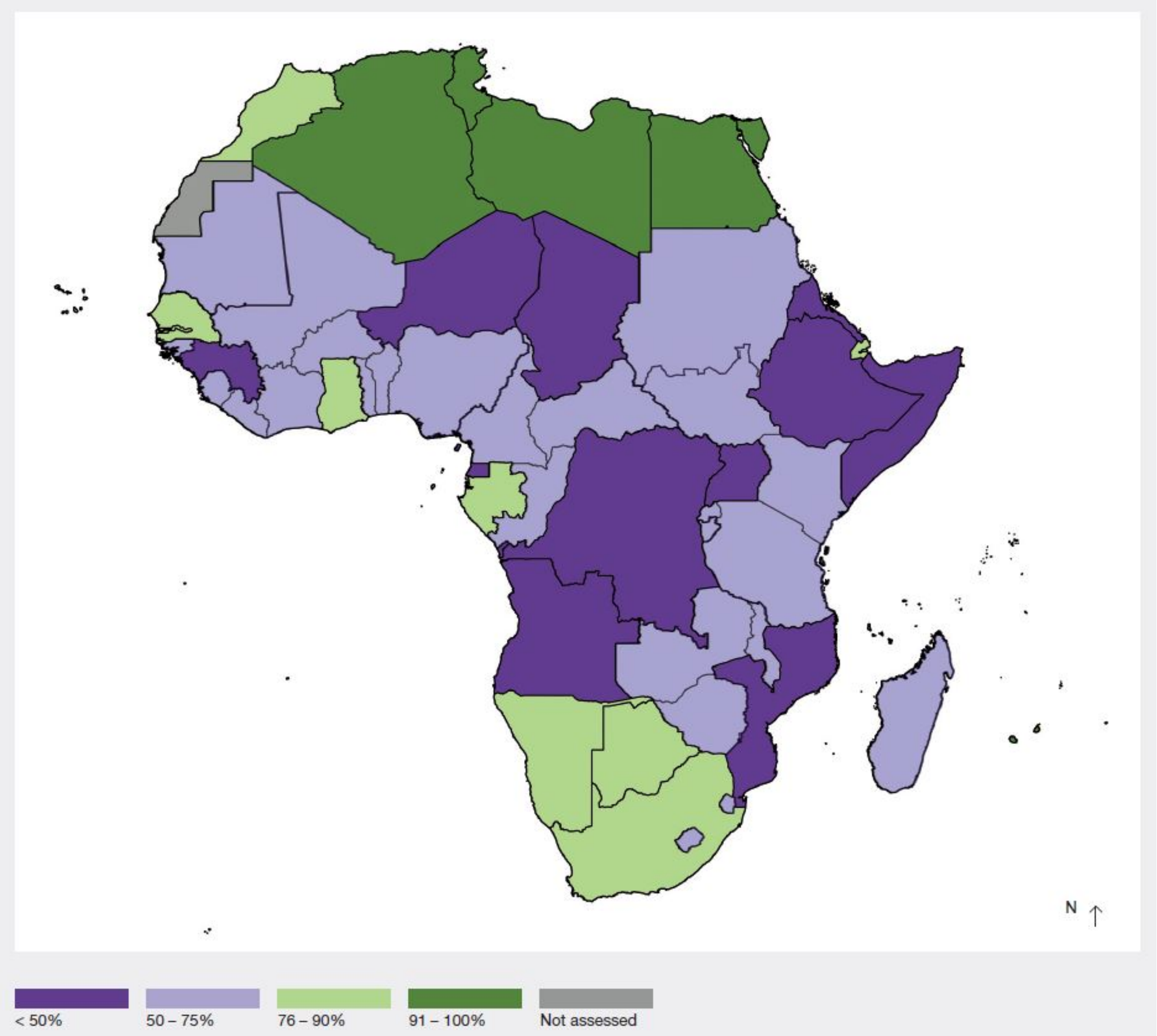


Figure 1.7: Proportion of the population in 2015 using basic drinking water services. Source: WHO-UNICEF (2017).

Growing water scarcity, a central issue addressed by the Africa Water Vision and a global priority expressed through SDG6, is not entirely due to natural phenomena. It is also related to water governance, investments and low levels of development and exploitation of water resources. According to the Water Vision, too much water is allowed to go to waste in Africa. “For example, the average level of unaccounted-for water is about 50% in urban areas, and as much as 70% of the water used for irrigation is lost and not used by plants.” Most countries also “have substantial underutilised potential for irrigation expansion (about 45 million hectares, according to an FAO estimate). In fact, two-thirds of African countries have developed less than 20% of their potential. In the whole of Africa, about 6% of the cultivated area is irrigated… The scope for expanding irrigation is, therefore, considerable [and]… there is an even greater scope for expansion of rain-fed agriculture”.

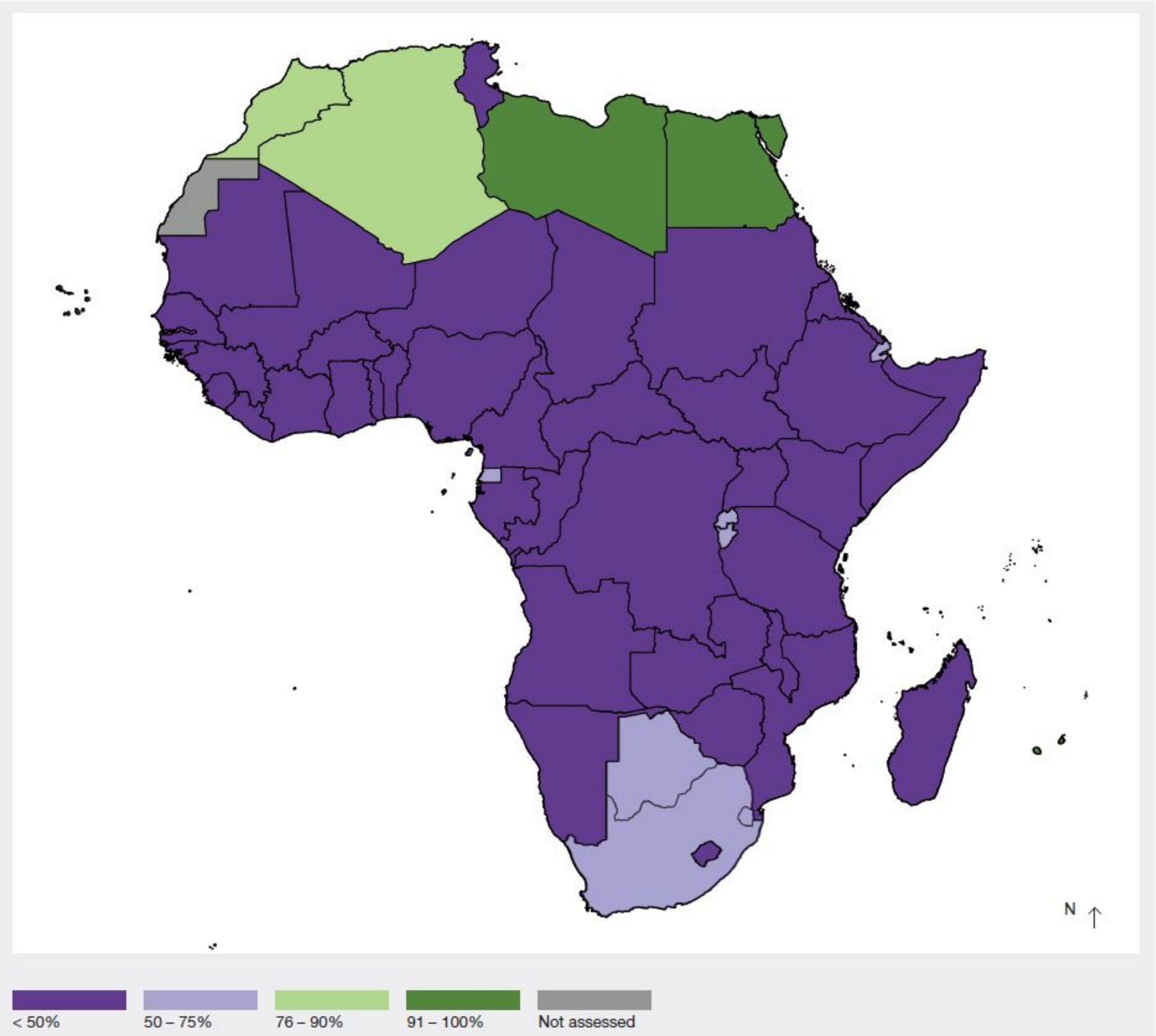


Figure 1.8: Proportion of the population in 2015 using basic sanitation services. Source: WHO-UNICEF (2017).

Water is an increasingly precious and coveted resource on the continent. As such, water management issues in Africa goes well beyond the production of food to involve complex governance and political issues from local to regional scales. It is necessary, therefore, to address the issue in the context of water security and in relation to the importance of water for food, energy, health and livelihood securities.

One feature typical of the hydro-geographic conditions found in Africa is the often markedly uneven distribution of water resources in the continent's basins. About 66% of Africa is arid or semi-arid, while most Africans rely on rain-fed agriculture and groundwater for domestic supply, particularly in rural areas (Faurès *et al.*, 2008). In fact, more than 300 million people in sub-Saharan Africa, from North Africa and the Sahel to East and Southern Africa, live in water-scarce environments, meaning that they have less than 1,000 m^3 per capita per year (UNEP, 2002).

This has consequences for water accessibility and use within and between subregions. Water-rich countries, i.e., those with abundant precipitation, such as Liberia, São Tome and Principe, Gabon in the Gulf of Guinea and Central Africa, contribute significantly to the volume of available water resources. On the other hand, water-scarce areas in North Africa, the Sahel and in East and Southern Africa, add little to that overall volume and, yet, draw a substantial share of the water they use from high-precipitation regions. The classic case for this is the Nile, whose upstream riparians are located in high-precipitation regions, while Egypt, the downstream riparian, is located in an arid region. A similar situation is found in the Zambezi and other river basins in southern Africa. Here the riparians to the north (Angola, Zambia, DR Congo, Mozambique) have abundant water resources, while the riparians to the south (in particular South Africa, Botswana, and Namibia) typically lack sufficient water resources and are highly reliant on water resources generated outside their borders. For instance, South Africa consumes 80% of all the water resources used in the SADC region, while contributing only 8 % to the region's water resources (Scheumann *et al.*, 2006). Such a situation necessarily holds potential for conflict. With the impact of climate change, precipitation changes could further limit water availability in some of these regions, though, in others, such as the Horn of Africa, greater rainfall could increase groundwater levels (Thangarajan *et al.*, 2016). The combination of changes in the flow of streams and rising temperatures is further expected to have broadly negative impacts on freshwater ecosystems and water quality (APP, 2015).

Africa must ensure the availability of water resources for the population's growing needs, the protection of very fragile and vulnerable ecosystems and the preservation of economic prosperity, both within countries and across national boundaries. It must respond to the broader challenge in a way that takes into account national interest as well as transnational interdependencies and collective securities. The Africa Regional Assessment thus involves consideration of the water policies and water profiles of different subregions, while taking into account major political challenges and the effect of long-term climatic impacts on water resources. Lake Chad is a classic example of how some of these challenges can come together. Despite the desiccation of the Sahara leading to considerable shrinkage of its ancient coverage, Lake Chad still plays a vital strategic role in regional water provision, local livelihoods, and resistance to desertification. It is a meeting point of eight major African member countries of the Lake Chad Basin Commission (Chad, Cameroon, Niger, Nigeria, Algeria, Central African Republic, Libya and Sudan), supplemented by three additional countries (Congo, Democratic Republic of Congo and Egypt), which have observer status in the Commission. It is also feeling the full impact of the insurgent terrorist movement of Boko Haram, which is causing a refugee crisis and serious water access and food supply challenges all around the Lake Chad area.

In a different but related case, Lake Malawi, also known as Lake Nyasa, has been a point of contention between Malawi and Tanzania since at least 1967. While the boundary dispute centred initially on issues of sovereignty and livelihoods and on the socio-environmental impacts (flooding) of the Kariba dam construction (Mayall, 1973), Malawi's oil exploration initiative, started in 2012, has revived tensions between the two countries. Control of the Nile River waters, e.g., through dam construction, is another important case study that is presently placing Egypt, Sudan and Ethiopia in potential opposition. It is a classic case of common property resource and collective action, magnified by international and intergovernmental complications.

The assessment will thus need to tread carefully in order to capture the critical connections that can turn into major disruptors of delicate mutual relationships between people, socio-political systems and ecosystems. Reference to existing transboundary water management initiatives and community-based water management schemes (e.g., Box 1.8 in 1.3.8.1.1) must be made to capture all the possibilities of developing a solution. Amidst economic challenges and political turmoil, there are many promising approaches to water governance and transboundary water resources management. Sub-Saharan Africa is, for this reason, especially well-suited to identify lessons learned in the implementation of transboundary water management schemes and to derive recommendations from successes as well as failures.

1.3.4.3 Energy in Africa

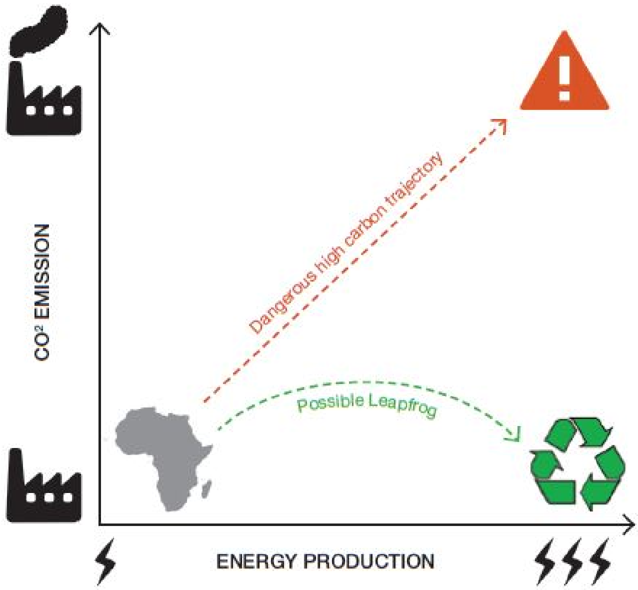
Energy comprises another critical component of the nexus. Energy is required for food production (especially irrigation) and for water supply, including the extraction, purification, and distribution of water (Bazilian *et al.*, 2011; Bach *et al.*, 2012). Woodfuel accounts for more than 80% of primary energy supply, and more than 90% of the population rely on firewood and charcoal for energy, especially for cooking (see chapters 2 & 4) Access to modern energy services is critical for socio-economic development (WEC, 2005). Africa's energy demand is expected to grow annually by 5% until 2040 and South Africa has nearly a third of the region's installed capacity (40 GW out of the 125 GW) (Fakir, 2012). Outside of South Africa, renewable hydropower provides 70% of all electricity to sub-Saharan Africa, although less than 30% of the population is connected to the grid (Fakir, 2012). In Africa, oil and gas reserves are concentrated in North and West Africa, as well as recent discoveries in East Africa. Hydroelectric potential exists in Central and Eastern Africa, as well as coal extraction in Southern Africa, cognisant of debates in this regard, however (WEC, 2005). Reliance on traditional biomass, as the main source of energy, is particularly high in Africa, where biomass accounts in some countries for 80% of primary energy supply and up to 95% of total consumption (IAEA, 2002; WEC, 2005; UNECA, 2006). The considerable solar and other renewable energy potential of Africa is yet to be fully exploited.

All methods of energy production, including renewables, have impacts on biodiversity and ecosystem services. However, the utilisation of new and renewable energies is an economically and environmentally attractive alternative to fossil fuels (Heinberg, 2016) (Box 1.5). These types of energy sources are renewed within a lifetime through natural processes comprising wind, wave, solar, biomass (wood fuel, agricultural residues, animal wastes, biofuel and other bioenergy), hydropower and geothermal energy (UNECA, 2006). Sustainable energy is defined as energy which is replenishable within a human lifetime and which causes no long-term damages to the environment (UNECA, 2006).

Renewable energy technologies are often considered the most appropriate technology choice for most of rural Africa and they could provide a reliable and ecologically sound long-term alternative for many countries, including current oil-exporting nations, as many of them have abundant and unexploited biomass, water, solar and wind resources. There is considerable potential for hydropower development in Africa (1.5 million GWh per year according to Zarfl *et al.*, 2015), yet to date, only 7% of that potential has been harnessed (Blomfield, 2008). Unsustainable woodfuel (biomass) consumption practices have, however, locally led to deforestation (UNECA, 2006) and the planting of alien invasive trees for woodfuel has sometimes resulted in the loss of biodiversity in surrounding areas.

Box 1 5 The Africa energy challenge. Source: APP (2015).

Energy is now a priority focus of infrastructural investments for a majority of countries on the continent, as well as regional bodies such as the African Development Bank and the World Bank. According to the Africa Progress Report (APP, 2015), Sub-Saharan Africa's electricity consumption is less than that of Spain. Over 600 million people still do not have access to electricity, while Africa's poorest people are paying among the world's highest prices for energy. For example, a woman living in a village in northern Nigeria spends around 60 to 80 times per unit more for her energy than a resident of New York City or London! Energy-sector bottlenecks and power shortages cost the region 2-4 percent of Gross Domestic Product (GDP) annually, and, on current trends, it will take until 2080 for every African to have access to electricity. This challenge in itself could be a large investment opportunity for Africa. Millions of energy-poor disconnected Africans, who earn less than US$2.50 a day, constitute a US$10-billion yearly energy market. Africa, which has enormous potential for clean energy, through natural gas, hydro, solar, wind and geothermal power, should seek ways to move towards lower carbon options, as mentioned previously.



The energy "leapfrog"; renewable energy could do for electricity what the mobile phone did for telecommunications: provide millions of households with access to a technology that creates new opportunities (modified after APP, 2015).

As Koffi Annan stated in the foreword to the report: *"What would it take to expand power generation and finance energy for all? We estimate that investment of US$55 billion per year is needed until 2030 to meet demand and achieve universal access to electricity. One of the greatest barriers to the transformation of the power sector is the low level of tax collection and the failure of governments to build credible tax systems. Domestic taxes can cover almost half the financing gap in Sub-Saharan Africa. Redirecting US$21 billion spent on subsidies to wasteful utilities and kerosene to productive energy investment, social protection and targeted connectivity for the poor would show that governments are ready to do things differently. I urge African leaders to take that step".*

1.3.5 Invasive species

Thousands of species have been introduced into Africa from around the globe and many are successfully cultivated for agriculture, forestry, fisheries and horticultural purposes. These species, (animals, plants and micro-organisms), sustain human populations and bring economic benefit to the continent. Unfortunately, a small percentage of the thousands of species introduced are invasive. Invasive species can have serious negative impacts across all environments and many facets of life. The impact of invasive species in Africa has not been given adequate attention (Boy *et al.*, 2013), and despite commitment to several international agreements and targets (such as: Aichi Biodiversity Target 9, Article 8(h) of Convention of Biological Diversity, International Plant Protection Convention, Ballast Water Convention), little or no progress has been achieved to reverse the negative trends in invasive alien species (UNEP, 2012a; Tittensor *et al.*, 2014).

Invasive alien species have an extremely harmful impact on African biodiversity and on Ecosystem Services (such as the sustainable, adequate supply of usable water, fertile soil for crop farming, natural pasturage for stock farming, loss of access to fisheries and beneficial insects for pollination and natural pest control) (see Box 1.6).

In 2001 the cost of managing invasive species worldwide was estimated at $1.4 trillion or 5% of global GDP (Pimentel *et al.*, 2001). This percentage GDP is likely to be much higher in Africa due to the relatively ad hoc and reactive management approaches to biological invasions in most African countries, where the lack of available information on the financial costs of conservation is frequent (Frazee *et al.*, 2003).

Biological invasions may constitute a game changer, with unprecedented impacts that cost a great deal more to cure than prevent. Indeed, in many cases, complete "cure," in the sense of returning to the pre-invasion state, is impossible. For example, the water hyacinth is one of the world's most prevalent invasive aquatic plants and has invaded several freshwater systems in Africa and globally (Villamagna *et al.*, 2010). Biological invasions present a problem for many human activities, it is a threat to biodiversity and involves high costs for their control (van Wyk *et al.*, 2002). It has been calculated that in the Working for Water programme in South Africa, over 3 billion Rand (~$220 million) has been spent in dealing with the economic consequences of invasive plant species alone (Turpie, 2016). The Global Invasive Species Programme (GISP), CABI and IUCN developed a "toolkit" for the economic analysis of invasive species mostly focused on Africa (Emerton *et al.*, 2008). One of the studies cited (Wise *et al.*, 2007) assessed the economic impacts of five invasive alien species (one fish, one insect, the water hyacinth and two species of weeds) in different areas of Africa. Costs were significant at an individual level, ranging from 0.57 to over $400 per capita per year, impacting poor and vulnerable communities of farmers and fisherfolk.

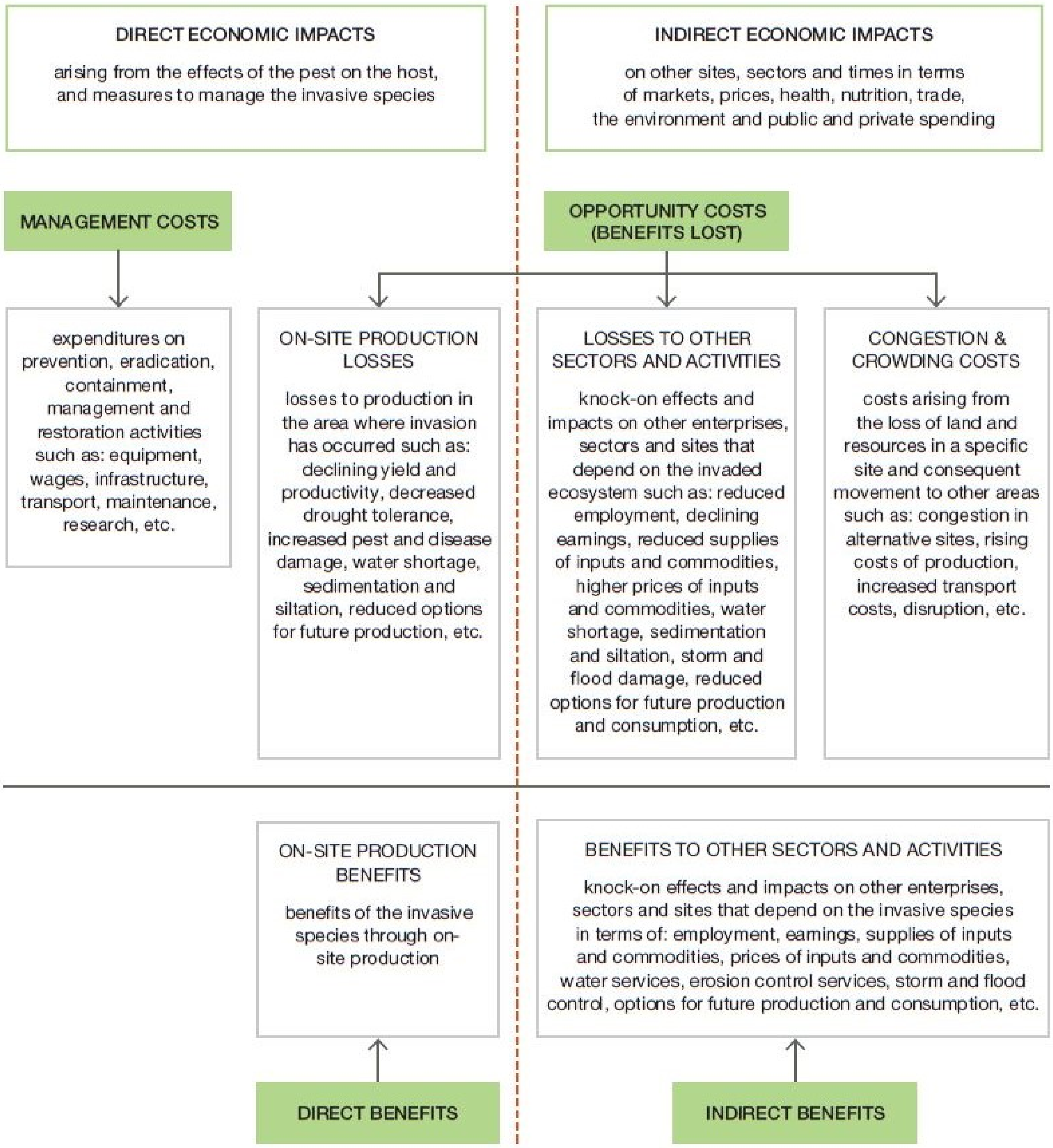
The most cost-effective, short-term actions called for are: firstly, prevention of introduction of known and potentially invasive species into each country, using screening at all points of entry, and secondly, their early detection and eradication where possible, using mechanical and chemical means (Preston *et al.*, 2000).

With increased international trade and transport, many more invasive species could still be introduced into Africa. Countries need to collaborate to manage the pathways of introduction to reduce the arrival of new potentially invasive species (international obligations to manage pathways covered in Chapter 4, section 4.2.2.4.1). Invasive species do not respect political boundaries and, thus, governments across the continent need to collaborate (see Chapter 4, section 4.2.2.4).

Efforts to protect Africa's rich natural resources, food production and human livelihoods from the impacts of invasive species will require investment from governments. Lack of taxonomic expertise and a dwindling number of trained taxonomists employed in Africa and around the world will negatively impact efforts to address the issue of invasive species (Pyšek *et al.*, 2013). Adequate information on presence and impact of invasive species is vital for planning, but not available in many countries. Clear national and regional management plans for high-risk species need to be developed and implemented. The challenge is particularly acute for small island developing states (SIDS), and integrated coastal management is generally the recommended strategy that should help reduce the vulnerability and enhance the resilience of SIDS facing invasive species (Cohen *et al.*, 2014). Of particular interest are research initiatives and networks devoted to reducing the rates and impacts of biological invasions by furthering scientific understanding and predictive capability, and by developing research capacity

Box 1 6 Direct and indirect impacts of invasive species and the benefits of their control. Source: graphic adapted from Emerton *et al.* (2008).

Invasive species are harmful to Africa's rich biodiversity, reduce life sustaining ecosystem services and have a serious economic impact for African countries. There is an urgent need to identify their pathways to prevent invasions into new areas. It is also urgent that African countries apply risk assessment approaches to identify the needs and types of management that is relevant to combat this biological invasion. This can be accomplished by sharing good and bad experiences in invasive species management between neighbouring countries and other regional bodies inside and outside the continent; and by allocating significant funds for management of invasive species by governments rather than be left to foreign-funded projects.



(elaborated on in Chapter 4, section 4.2.2.4). South Africa, for example, has established scientific and participative networks (http://academic.sun.ac.za/cib/ and http://www.invasives.org.za) in order to tackle the country's environmental and socio-economic issues associated with invasive species. Such initiatives have engaged citizens in national monitoring networks and scientific knowledge on invasive species (van Wilgen *et al.*, 2014), and should be promoted across the African continent.

Protection of environmental services from invasion and management of invasions in these high biodiversity areas should be given priority. Intergovernmental sharing of information and collaboration to prevent the introduction of invasive species into Africa should be the primary approach to limit the threat of invasive species. Such sharing of expertise and joint funding would minimise the cost and maximise the benefits of remedial environmental and socio-economic action for individual countries (Boy *et al.*, 2013). It is inefficient and ineffective to treat each invasion in isolation. It is, therefore, imperative that national governments and regional bodies adopt a biosecurity approach defined as "a strategic and integrated approach that encompasses the policy and regulatory frameworks (including instruments and activities) that analyse and manage risks in the sectors of food safety, animal life and health, and plant life and health, including associated environmental risk" (FAO, 2007b).

Some of these impacts are the unintended consequences of well-meaning development initiatives. For example, *Prosopis juliflora* (known by many in Ethiopia as the Devil Tree) was introduced through agro-forestry initiatives to many semi-arid parts of Africa. The advantages and negative impacts of introduced *Prosopis* have been explored. The negative impacts include impenetrable thickets along watercourses; invasion of pastureland; harmful effects of thorns; and reduction of growth of indigenous plants (Mwangi *et al.*, 2005; Maundu *et al.*, 2009). Through shifts in vegetation biomass and soil properties (Ilukor *et al.*, 2016) it, directly and indirectly, affects the food security of those in already economically and politically marginal situations (Maundu *et al.*, 2009; Shackleton *et al.*, 2014). It is essential that development agencies adopt a thorough risk analysis process to minimise the chances of scoring disastrous "own goals" through well-intended species introductions.

For over a hundred years, biological control, namely the introduction of host-specific natural enemies of the target invasive species, to permanently suppress the populations of invasive species to a tolerable level has been successfully practised in Africa. Despite the fact that some unintended consequences may have led to the concern that possible environmental benefits do not warrant risks (Simberloff, 2011), biological control is still considered the most cost-effective, long-term action to manage established invasive species even given costly research and investment in quarantine facilities (van Wilgen *et al.*, 2011). Yet, biological control requires flexibility in policy design and application to account for uncertainty and cost-benefit issues (Keller *et al.*, 2009; Sims *et al.*, 2016). It is mandatory to test the safety and potential effectiveness of the candidate biocontrol agents (namely whether or not they are host-specific to the target invasive species, and present no threat to indigenous or economically important species, and whether they are able, under laboratory conditions, to reduce the growth and reproduction of the invasive species). Human capital development in all fields of invasive species management is required in order for Africa to prevent new introductions and to reduce the impact of existing invasions.

1.3.6 Habitat degradation and restoration (marine and terrestrial)

Land degradation is a scientific conception, based on the idea that ecosystems tend to reach a stable stage that can be disturbed by human use of resources. But the rise of the disequilibrium concept in ecology, combined with works of archaeologists and anthropologists who described the practices of local populations related to the environment, make it possible to consider some of these practices as part of the natural functioning of ecosystems, and factors that contributed to their present state.

Land, freshwater, estuaries and the oceans are a finite, non-renewable natural capital, and the biological productivity generated is used by people for food production/harvesting and therefore the degradation of the land and water has a direct impact on agricultural and fisheries productivity (Chasek *et al.*, 2015). Land-use changes in Africa have transformed land cover to farmlands, grazing lands, human settlements and urban centres at the expense of natural vegetation. These changes are often associated with deforestation, overgrazing and deteriorating rangelands, decreased access to potable water, erosion, pollution, overfishing, biodiversity loss and land degradation (Maitima *et al.*, 2009; Nachtergaele *et al.*, 2011) (see Chapters 4 and 5). Land degradation and desertification can be defined as a persistent reduction or loss of the biological and economic productivity resulting from climatic variations and human activities (Adeel *et al.*, 2005; Bai *et al.*, 2008; Vogt *et al.*, 2011), which is sufficiently broad to also be applicable to the marine and freshwater environment.

Thirty-three terrestrial ecoregions with globally important biological values that are highly threatened were distinguished by Burgess *et al.* (2006), most of which are on offshore islands (twelve) or on mainland montane areas (fourteen) and seven in the lowlands. Endangered ecoregions are shown in Figure 1.9. Six marine ecoregions with the highest biodiversity significance were distinguished by Tear *et al.* (2014) among which are the Mascarene Islands of the Indian Ocean bordered by the Kenya and Tanzania coastal region and the North-western Madagascar coastal region (Figure 1.10). Selig *et al.* (2013, 2014) developed an index based on a global assessment of the condition of marine biodiversity using publically available data to estimate the condition of species and habitats within 151 coastal countries. They also found a strong positive relationship between the Human Development Index and resilience measures that could promote greater sustainability by reducing pressures. This relationship suggests that countries lacking effective governance will further jeopardize their ability to maintain species and habitats in the future.

Causes of land and water degradation in Africa include, among others, rising consumption patterns, demographic growth, conflicts and wars with internal and external displacement, inappropriate soil management, pollution, insecurity in land tenure, variation of climatic conditions and the intrinsic characteristics of fragile soils in diverse agro-ecological zones (Thiombiano *et al.*, 2007) (further information in Chapter 4, with implications considered in Chapter 5). Land degradation severity, extent and trend is variable in Africa and affects about 46% of the continent, and the semi-arid areas of Africa are particularly vulnerable, as most of the area is characterised by fragile soils, localised high population densities, and low-input agriculture (WMO 2006; Bai *et al.*, 2008).

Of the productive land area, up to two thirds are estimated to be affected by land degradation (Jones *et al.*, 2013; UNCCD, 2013), and desertification affects 45% of Africa's land area with 55% of this area at high or very high risk of further degradation (UNEP/ELD, 2015). At the same time, flora and fauna in desert areas suffer the effects of climate change (Durant *et al.*, 2014) and populations of megafauna, in particular, are collapsing.

It is expected that the interrelation between land degradation and climate change may lead to an expansion of land degradation in the future (Thiombiano *et al.*, 2007; Vu *et al.*, 2014). A strategy against land degradation has been developed for Africa in support of the United Nations Convention to Combat Desertification (UNCCD) to prevent, control and reverse land and water degradation in areas with medium to high production potential that are critical for people's livelihoods (MA, 2005; GEF, 2014; UNCCD, 2014; UNEP/ELD, 2015).

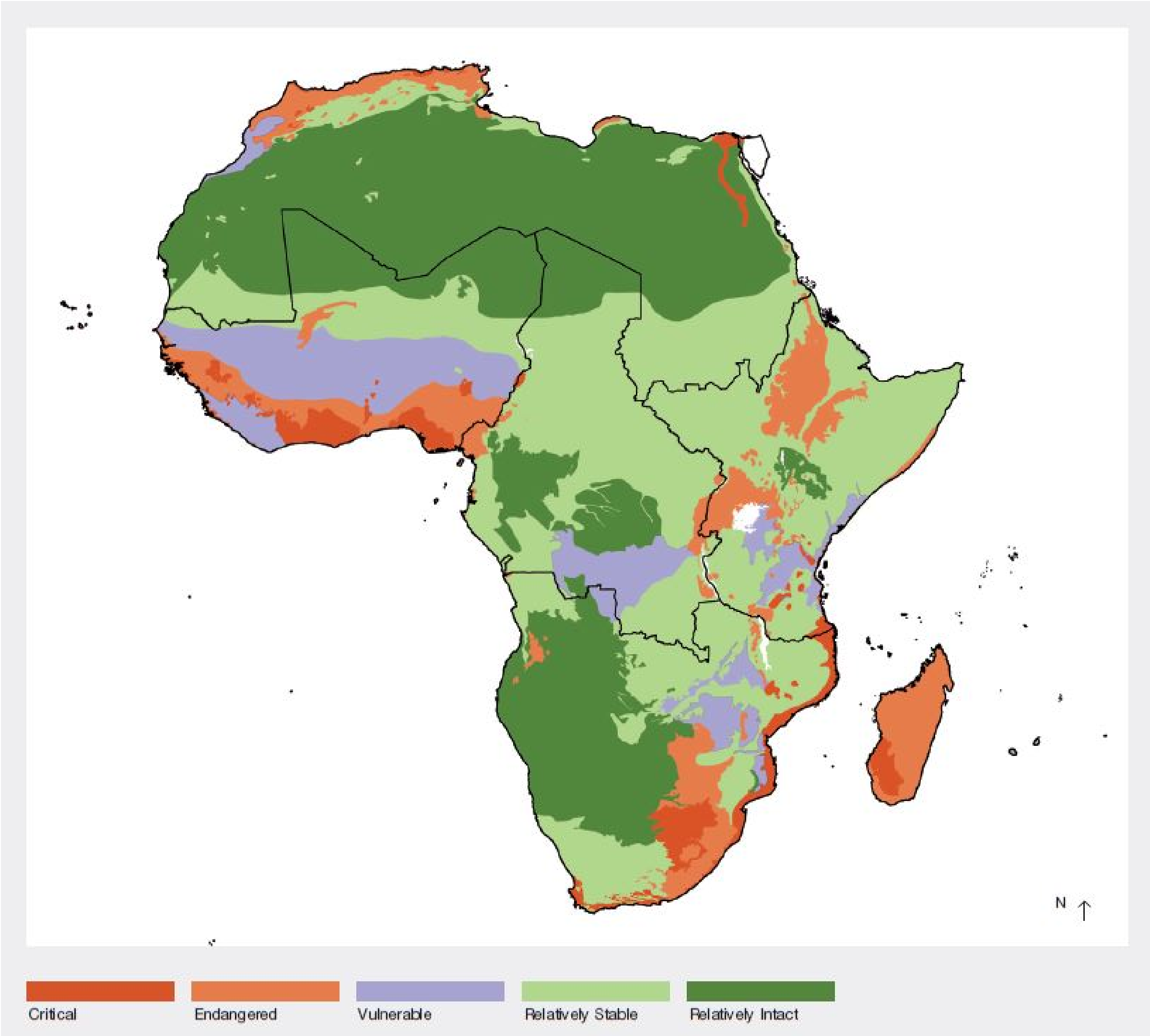


Figure 1.9: Conservation status of terrestrial ecoregions of Africa. Sources: Olson *et al.* (2001); Burgess *et al.* (2006).

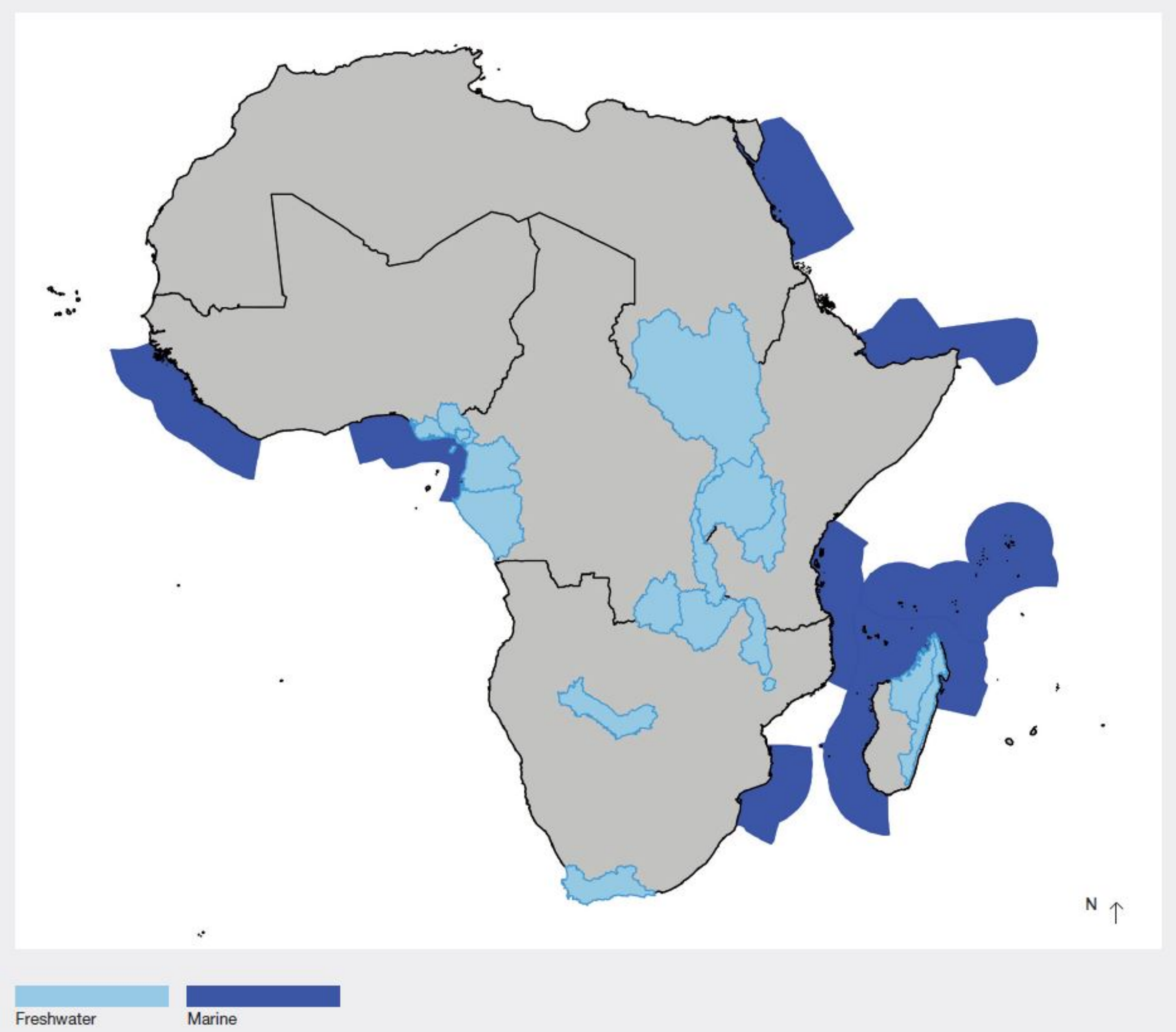


Figure 1.10: Marine and freshwater ecoregions in Africa with the highest biodiversity significance rating. Sources: Abell *et al.* (2008); Tear *et al.* (2014).

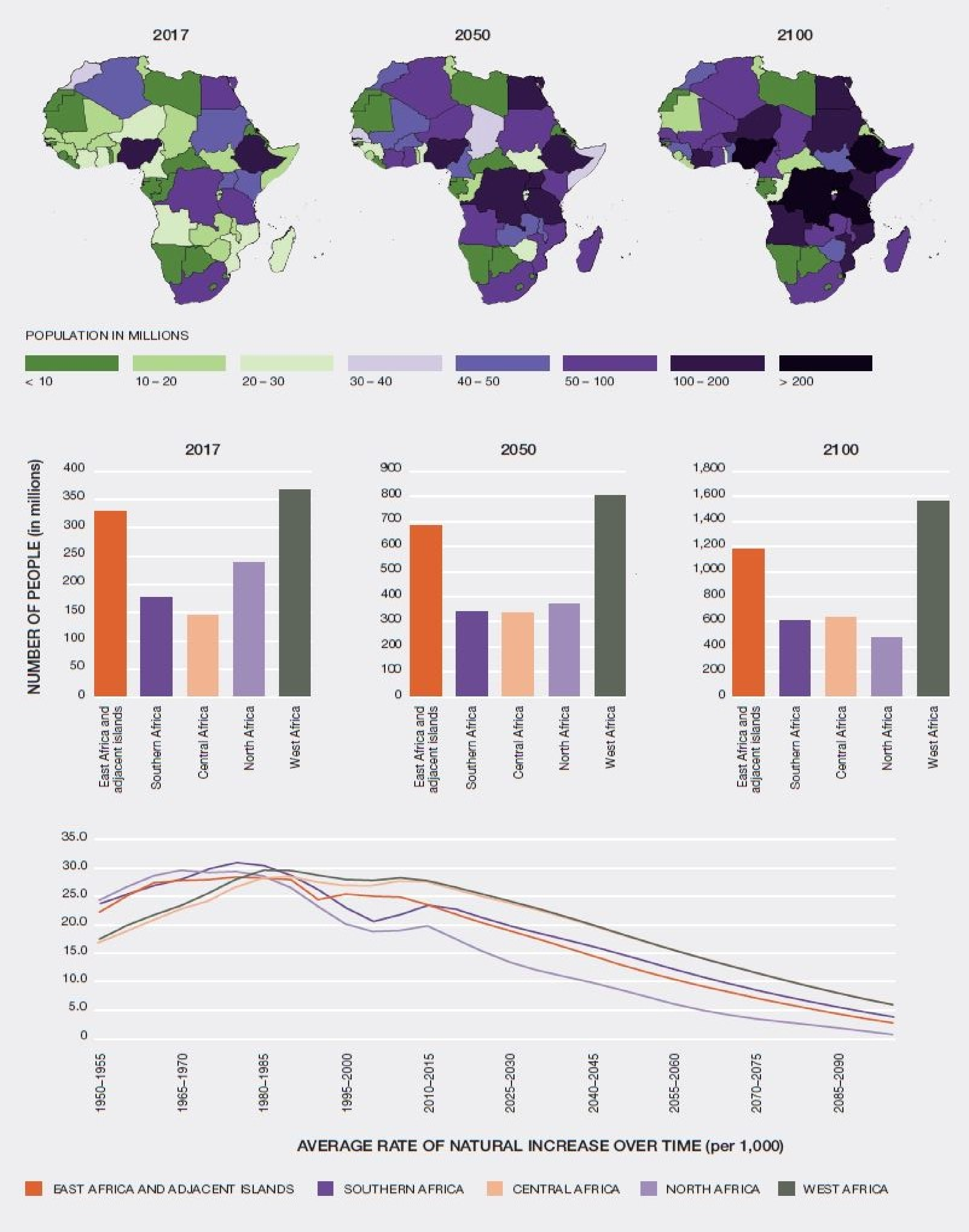
1.3.7 Population, poverty and health

1.3.7.1 Population dynamics and their implications

In 2017, Africa's population reached 1.25 billion[1], representing 16.4% of the world population. The UN's medium estimates suggest that population growth will remain strong in the coming decades so that by 2050, one in four people in the world will be African (26.2% of the world population). The accuracy and availability of population census data vary but the data that do exist suggest highly varied trends and prospects across the region (Figure 1.11). Nevertheless, by 2100, 19 African nations are expected to reach populations of >75 million people with the total population of the four most populous African countries anticipated to be approaching 1.7 billion, considerably more than the entire population of Africa in 2015 (UN, 2015a). These estimates are highly dependent on fertility rates, but recognise that 19 of the world's 22 'high fertility' countries (where women have 5 or more children on average) are located in Africa. Africa also shows the world's greatest increases in life expectancy and reductions in child mortality, though again there are distinct regional variations (UN, 2015a).

[1] Based on UN estimates from http://www.worldometers.info/world-population/africa-population/ as at 18 August 2017.

Strong population growth inevitably presents challenges which need to be effectively managed. However, it also presents opportunities. Africa's population will be relatively young (Figure 1.11), with more favourable ratios between working and non-working aged people compared to certain other parts of the world – the so-called 'demographic dividend' (Canning *et al.*, 2015). By 2040, the continent will be home to the largest working-age population in the world (Roxburgh *et al.*, 2010). Furthermore, the continent still retains important global resources in terms of commodities, untapped potential for food production and latent consumer demand (UN, 2015a). These are some of the reasons why Africa has been termed the 'sleeping giant of the world economy' (Roxburgh *et al.*, 2010).



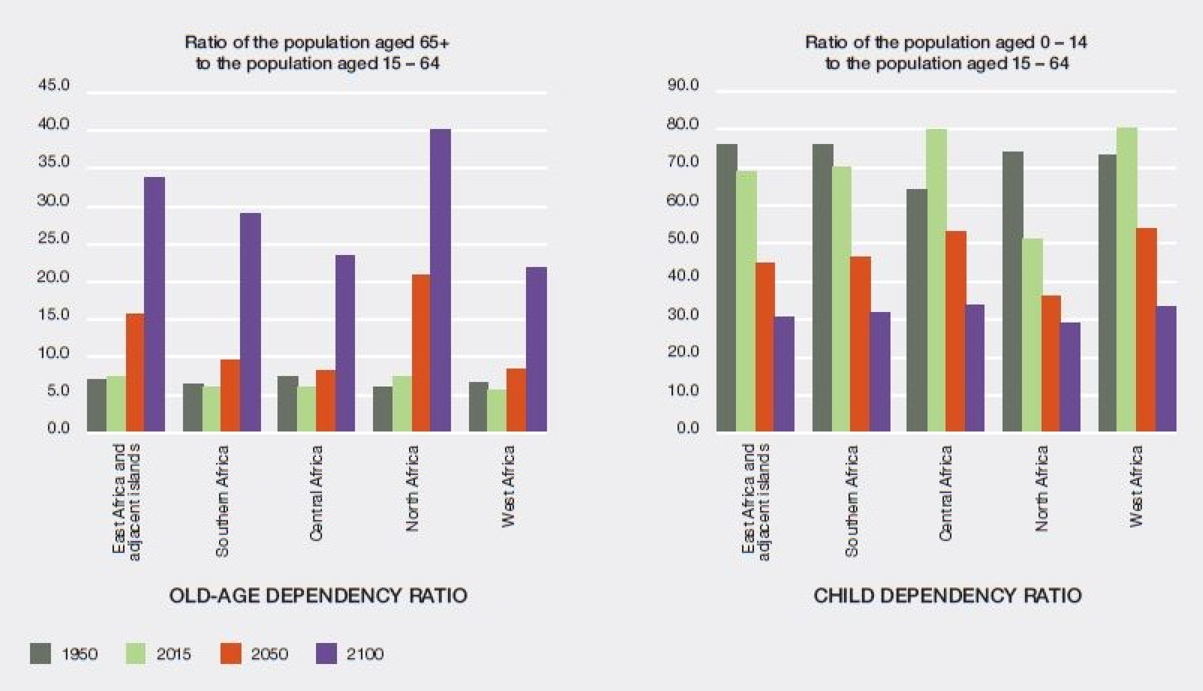


Figure 1.11: Current and projected population characteristics for Africa. Left top and centre: Population trends in Africa and per subregion. Left bottom: Trends in the average rate of natural increase over time. Right top: Proportion of the population dependent on working age population. Sources: UN (2017); data retrieved from https://esa.un.org/unpd/wpp/Download/Standard/Population/.

These opportunities are exciting for the future of Africa, but the process of realising them comes with challenges and risks. Innovation and technological development have proved to be strongly positive counters to early ‘Malthusian’ concerns of population-environment pressures, but environmental degradation and biodiversity losses remain major concerns (Canning *et al.*, 2015). Solutions need to be multi-faceted and take account of the lag between population control measures and their impact (Bradshaw *et al.*, 2014). Africa starts with the benefit of low ecological and carbon footprints compared with other parts of the world, but there are still likely to be challenges associated with balancing increasing economic growth, rising population and population densities with the need to protect, conserve and enhance biodiversity and ecosystem services (UNEP, 2016).

Chapter 4 provides an in-depth examination of anthropogenic drivers (see sections 4.2.2 and 4.3.4), their inter-connections with natural drivers and their impacts on land degradation, sustainable use, conservation and the food-energy-water-livelihood nexus. This includes consideration of uneven distributions in pressures, dependencies and outcomes. A few illustrative examples are helpful to introduce some of the complexities around population dynamics. For example, when considering population growth, trends are expected to be particularly strong in sub-Saharan Africa. Since this is also where people are most dependent on agriculture for their livelihood there is likely to be an associated pressure on material contributions from nature, both in terms of food and also water (Mutanga *et al.*, 2012). Looking at water stress more closely, it has been estimated, perhaps conservatively, that around 400 million people in Africa already live in water-stressed countries and this could double by 2050 as a result of population growth and also climate change (Mutanga *et al.*, 2012; and see Figure 1.12). Africa’s coastline is another location already being particularly affected by population dynamics and associated drivers. Here, population pressure and the strong reliance of local populations on mangrove ecosystems are just some of the reasons behind mangrove degradation and loss, with estimates from West and Central Africa suggesting losses of up to 30% over the last 25 years (Diop *et al.*, 2016). In turn, local populations lose the protection mangroves offer against storms and sea level rise (Bosire *et al.*, 2014). The case of mangroves (see Chapter 2) also illustrates how local dynamics can have regional and global impacts, for example through the loss of nursery habitats for many fish species (Arthurton *et al.*, 2006). In rangelands, too, population pressure is considered to be at the heart of biodiversity loss and degradation, though intricately linked with other factors such as poverty, development needs and related resource extraction, conflict in the wider region, climate change and the impacts of invasive species (Kideghesho *et al.*, 2013).

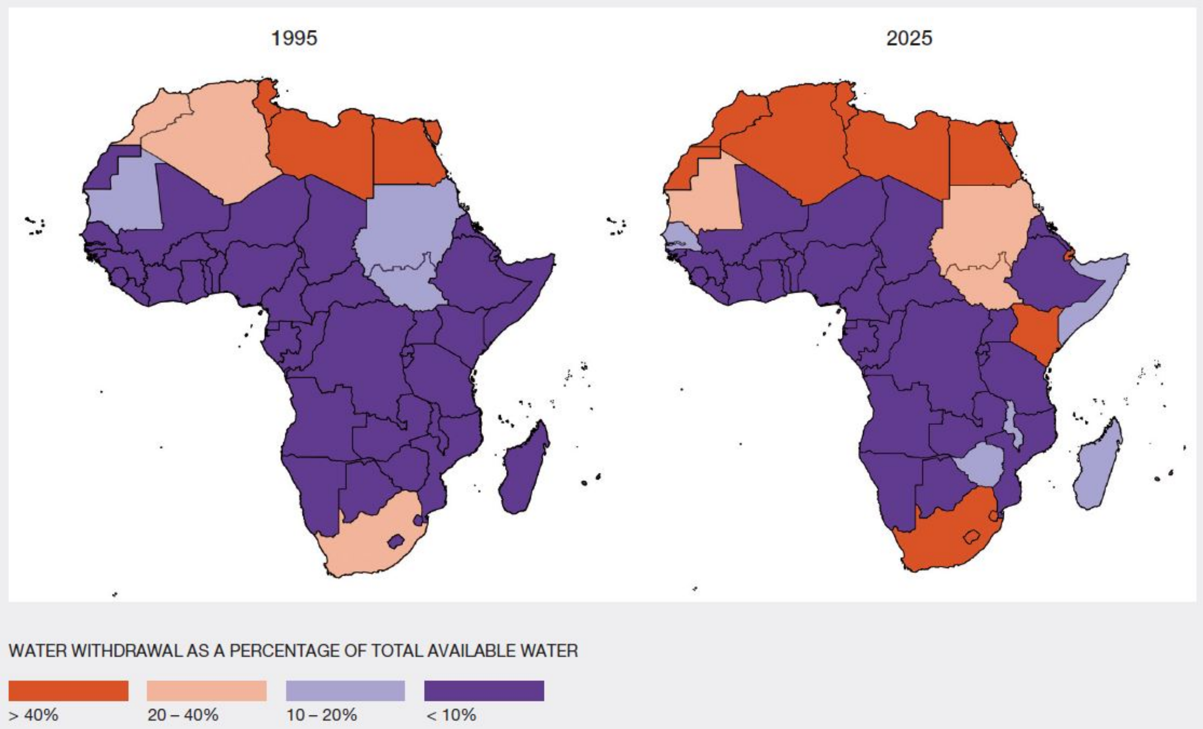


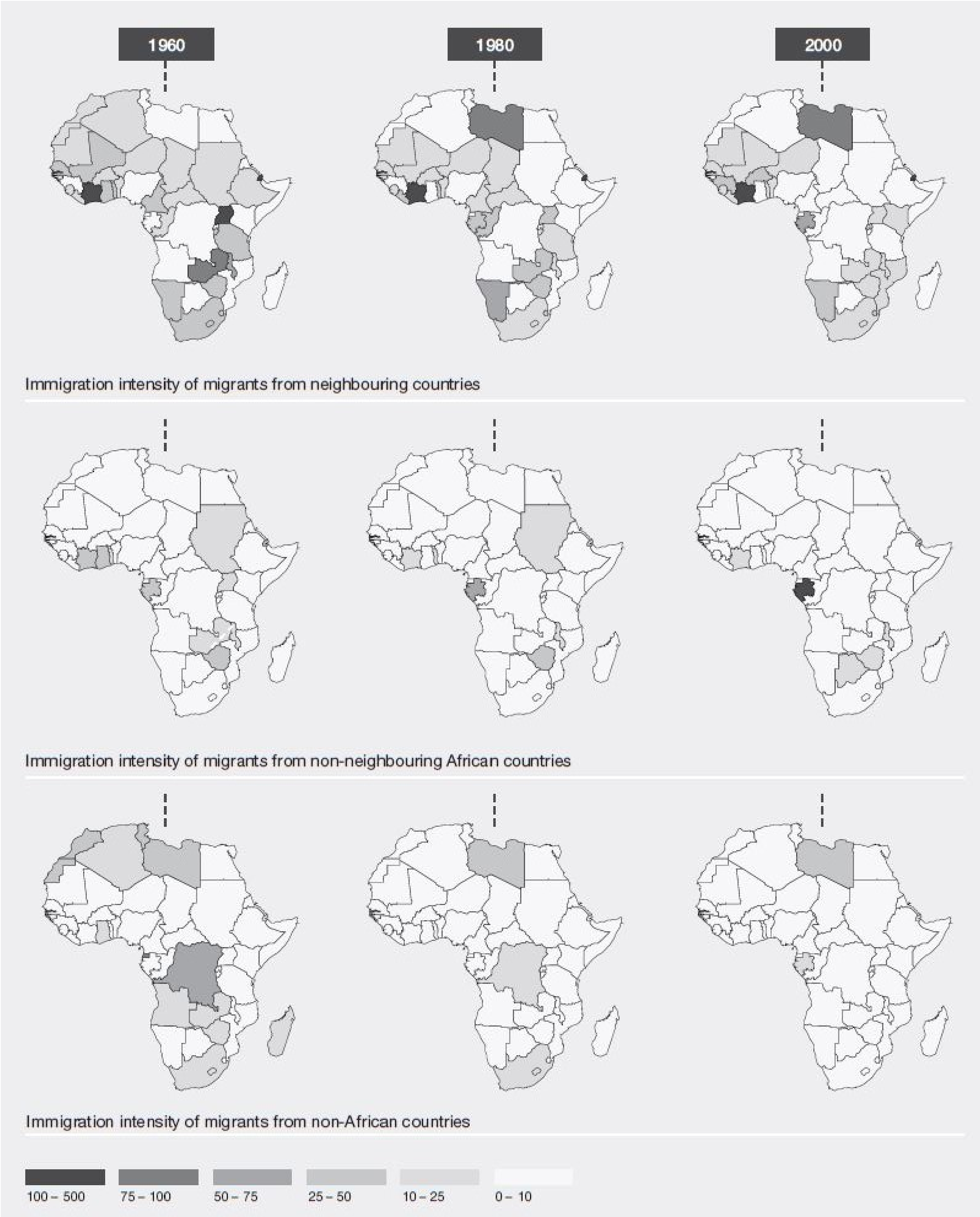
Figure 1.12: Past (1995) and future (2025) water-stressed countries (water withdrawal given as a percentage of the total available water). Source: https://www.grida.no/resources/5625.

Population dynamics are strongly connected to those of land cover and land-use (also see Chapter 4, section 4.2.2.1), including conversion of land to agricultural uses, urban settlement and the development of transport and other infrastructure. Africa's migration and urbanisation processes are complex, varied and often inter-related, though detailed analysis is often hampered by a lack of data and inconsistent definitions (Potts, 2009, 2012; de Brauw *et al.*, 2014). Nevertheless, by 2050 it is expected that more than half of all Africans will live in urban settlements of one form or another (UN, 2015b). Some of the increase will be in emerging megacities, but also through the growth of secondary and smaller settlements (UN Habitat, 2014; Figure 1.13). Conventionally, rural-urban migration has been seen as a major driver of the growth of urban areas, with implications for social structures and land management in rural and urban areas (de Brauw *et al.*, 2014). However, demographic factors are also important and urbanisation trends are not uniform with increasing evidence of urban-rural migration, e.g., in parts of central, eastern and western Africa (UN Habitat, 2014) and evidence too of cyclical migration patterns (Potts, 2009; Anderson *et al.*, 2013).

Models suggest a six-fold increase in urban land cover between 2000–2030 (Seto *et al.*, 2012; Figure 1.14). Despite still making up a very small proportion of overall land area, the implications are nevertheless far-reaching. West Africa's Guinean forests are expected to be among the five biodiversity hotspots most threatened by urbanisation and 30% of Africa's Alliance for Zero Extinction sites could be affected (Seto *et al.*, 2012).

Other ecologically sensitive areas are also expected to be affected by 2040, including the Nile River region, the urban West African corridor between Abidjan and Lagos, the northern fringes of Lake Victoria and Lake Tanganyika in East Africa and Nigeria's northern Kano region (Anderson *et al.*, 2013). Population-related degradation and drainage is a growing problem for Africa's important and internationally recognised wetlands (Arthurton *et al.*, 2006). Since the wider impacts of activities are currently only poorly understood and monitored, the ecosystem contributions that wetlands provide are also poorly estimated (Barbier, 2016) and governance issues prevail (Feka, 2015). Chapter 4 (section 4.2.2) demonstrates how anthropogenic drivers affect biodiversity as a result of urbanisation, land cover changes and road incursion, amongst others. Habitat fragmentation is a well-recognised outcome and the viability of animal migration corridors can also be compromised (UNEP, 2015; Watson *et al.*, 2014). Urbanisation is thus inextricably linked to land degradation, biodiversity loss and habitat fragmentation alongside the development of transport routes and other development drivers.

As well as protecting biodiversity, there is a need to understand and account for the needs of urban dwellers. Their needs are not simply about ensuring that material requirements are met, but also that a good quality of life can be achieved as a result of other non-material and regulating functions of nature's contribution (see Chapter 2). In other words, urban dwellers do not simply require food, fuel and shelter for survival. Rather they should have the opportunity for a good quality of life, allowing for the spiritual, recreational and restorative benefits from urban nature and the chance to benefit from cool breezes, quiet spaces and shade. This inevitably requires consideration of waste and waste disposal, water, air, soil and noise pollution, urban climate and hydro-meteorological hazards all of which can impact nature and its contributions to a good quality of life, as is explored in Chapter 4 (section 4.2.2.4). Since urban areas are still largely developing, there is an opportunity to build towns and cities on the principles of sustainable resource use, including considering catchment to coastal processes, as part of a 'profound re-imagining' of existing and future urban transitions and the development of "innovations towards greener, healthier and more sustainable urban societies" (UN Habitat, 2014). Such profound re-imagining can include harnessing contributions from nature through regulation of drivers of poor health and well-being and ensuring heritage, identity and social practices are supported. While taking advantage of the opportunities that urbanisation brings, this assessment also recognises that the major part of Africa's population in 2050 will still live outside of urban areas in scattered settlements. The needs and aspirations of these people are also important, including indigenous and traditional peoples who choose to maintain their way of life (Abdel Rahman, 2009). Traditional and nomadic practices need to be recognised and supported, not least for their role in maintaining, conserving and supporting biodiversity. This is particularly important given that the peoples with these practices may be disconnected and marginalised from decision-making and their valuable and irreplaceable knowledge lost.


1960
1980
2000
Immigration intensity of migrants from neighbouring countries
Immigration intensity of migrants from non-neighbouring African countries
Immigration intensity of migrants from non-African countries
100 – 500
75 – 100
50 – 75
25 – 50
10 – 25
0 – 10

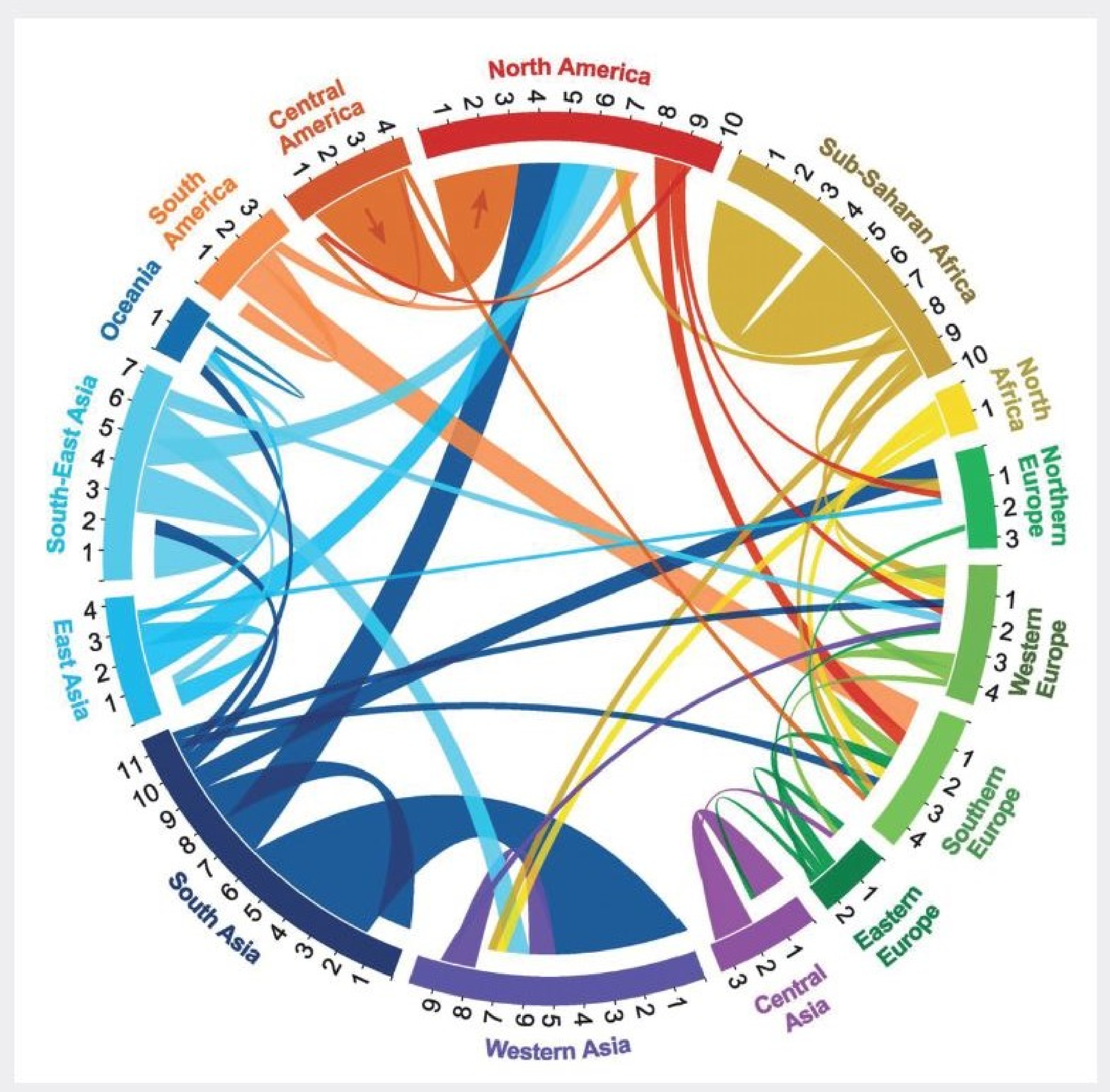
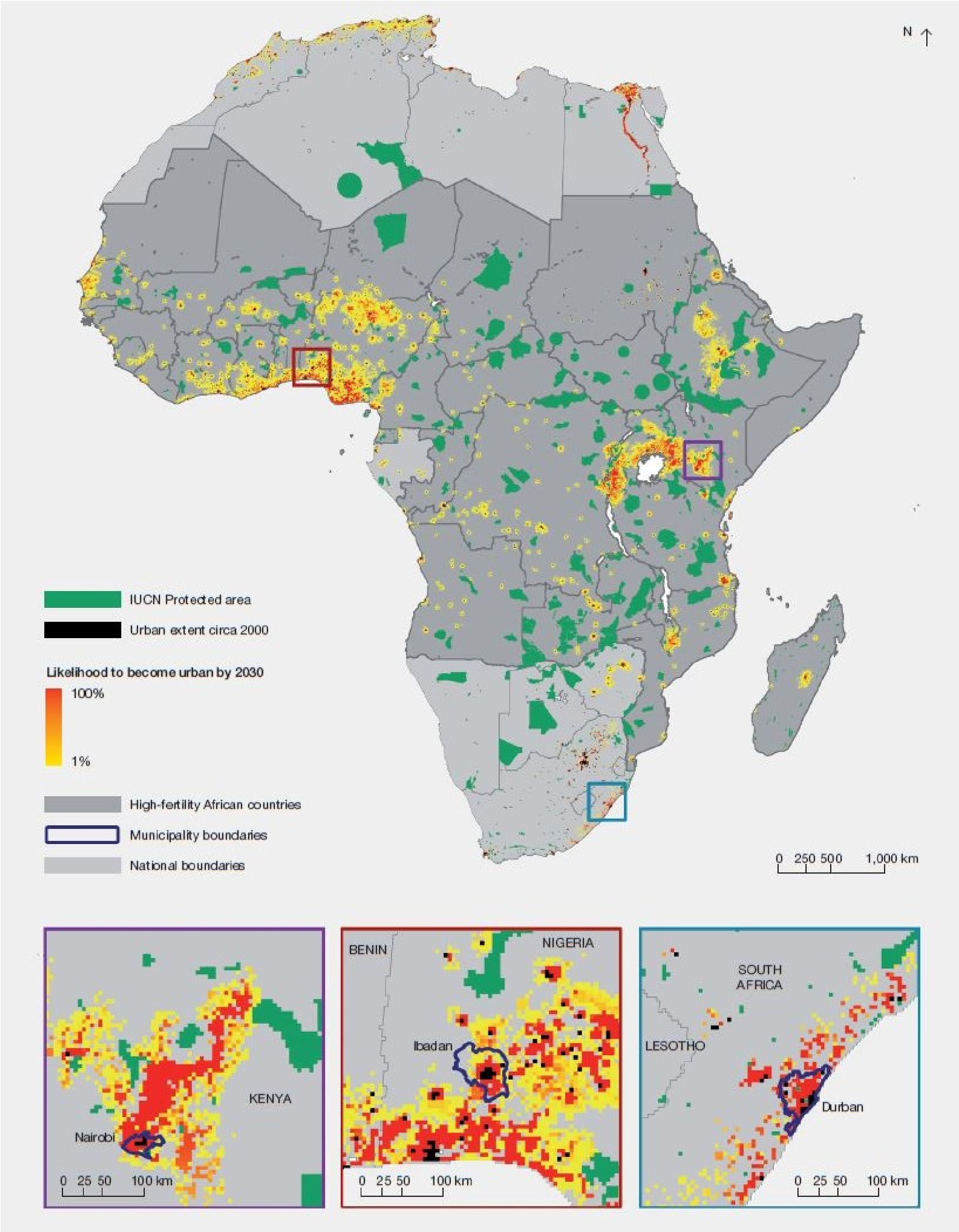


Figure 1.13: African migration patterns. Left: Evolution of immigration intensity from neighbouring, non-neighbouring and non-African countries (immigrants per 1000 inhabitants); Right: Circular plot of migration flows between and within world regions during 2005 to 2010. Tick marks show the number of migrants (inflows and outflows) in millions. Only flows containing at least 170,000 migrants are shown. Sources: Abel *et al.* (2014); Flahaux *et al.* (2016).


N
IUCN Protected area
Urban extent circa 2000
Likelihood to become urban by 2030
100%
1%
High-fertility African countries
Municipality boundaries
National boundaries
0 250 500 1,000 km
KENYA
Nairobi
0 25 50 100 km
BENIN
NIGERIA
Ibadan
0 25 50 100 km
SOUTH AFRICA
LESOTHO
Durban
0 25 50 100 km

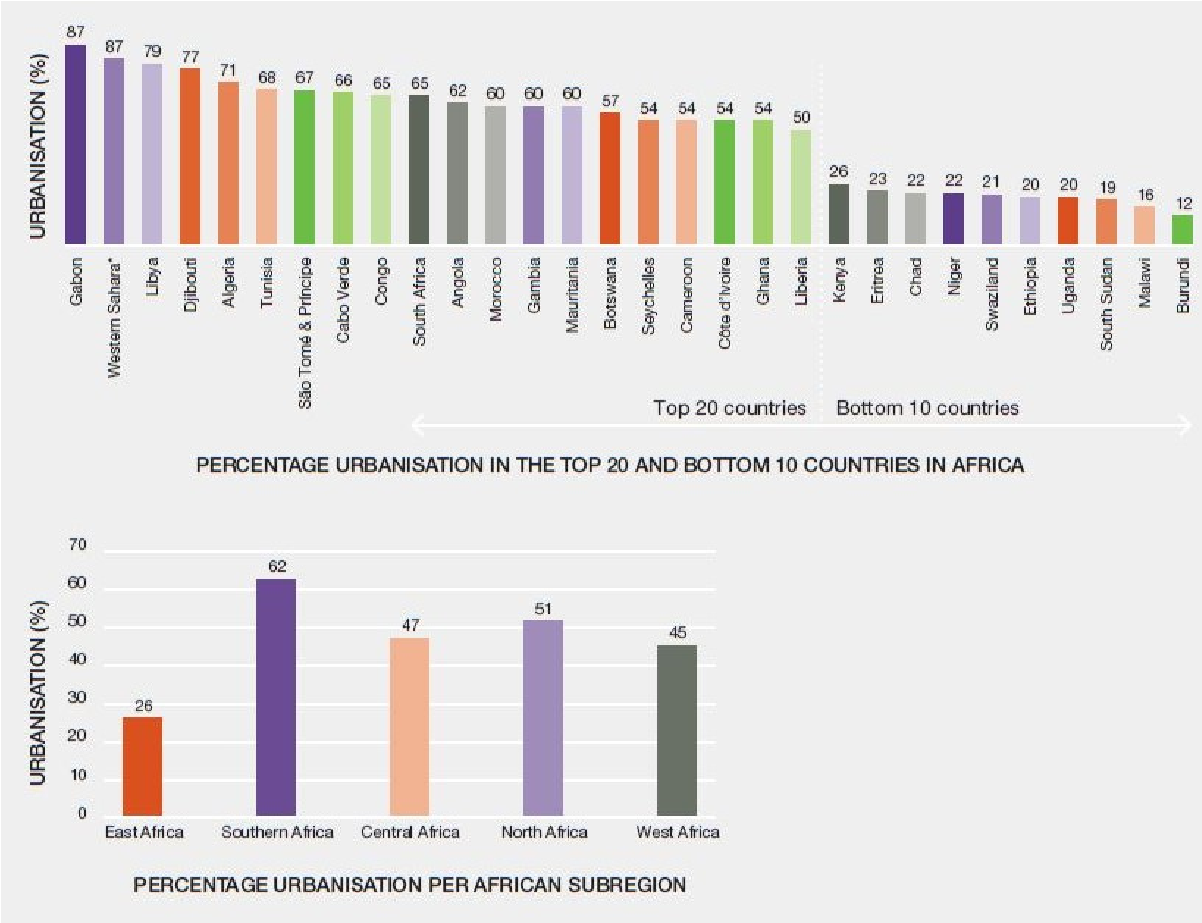


Figure 1.14: Current and future urbanisation in Africa. Left: Probabilistic forecasts of urban expansion by 2030 in Africa. We estimate the probability for each location by calculating the percentage of 1000 spatially explicit simulations of urban growth, in which that location becomes urban. We generated the 1000 simulations using Monte Carlo techniques. Probabilities vary from 1% to 100% from yellow to red on the maps. High rates of urban expansion are expected along the Nigerian coast and within the Lake Victoria Basin. Even in relatively lower-fertility countries such as South Africa, major urban centres are expected to grow well beyond their current municipal boundaries. Top right: Percentage urbanisation in the top 20 and bottom 10 countries and territories in Africa. Bottom right: Proportion of population in urban areas by region (2016). Sources: AU (2017); Güneralp *et al.* (2017).

1.3.7.2 Poverty and ecosystems

Information about population numbers, densities, distributions and flows in Africa is required for this assessment, but they only provide part of the picture of the human context of assessing biodiversity and ecosystem contributions in Africa. The relationships between people, nature and nature's contributions are also strongly connected to poverty and poverty dynamics, as is explored in detail in Chapter 4 (Section 4.3.1). In some instances, great strides have been made in tackling poverty in Africa. For example, during the period 1990–2012, there has been a reduction from 56% to 43% in the proportion of people in sub-Saharan Africa living on $1.90 per day, something which has been particularly marked since the turn of the new century (World Bank, 2015a). Rapid increases in population have, however, meant that despite these reductions in proportions, there are now more people experiencing extreme poverty than ever, especially in East and Southern Africa (IFAD, 2015; World Bank, 2015a). There are suggestions that reductions in the share of people in poverty are larger than estimated in official statistics, but Africa has still not reached the Millennium Development Goal to halve its 1990 extreme poverty rate by 2015 (taken as the proportion of people living on less than $1/day) (Christiaensen *et al.*, 2015; World Bank, 2016). Successes are inevitably affected by global as well as local drivers (Chuhan-Pole *et al.*, 2015). Some commentators suggest that the world food, energy and financial crises have contributed to slowing progress in recent years in Africa (del Ninno *et al.*, 2015; Chuhan-Pole *et al.*, 2015), but there are also suggestions that the continent's economies fared relatively well, were quick to rebound and retain strong growth in many areas (AfDB, 2010; Devarajan *et al.*, 2015). Nevertheless, poverty eradication and socio-economic development remain the number one priority for developing countries in Africa (McKay *et al.*, 2015; Palmer, 2015; UN, 2015c; Oldekop *et al.*, 2016).

Income-based measures show only part of the true extent of poverty, deprivation and associated inequalities. So-called multidimensional poverty takes a wider view and includes related characteristics such as health, education, living conditions and social inclusion (UNDP, 2016). Here too, there are many positive trends. For example rates of literacy, life expectancy and chronic malnutrition have all improved, but thresholds are very low. Indeed, according to the Millennium Development Goals report, during the period 2011–2013, sub-Saharan Africa was still the most food-deficient region in the world, with 25% of the population having faced hunger and malnutrition (AU, 2015a). One in five adults still cannot read and write (Christiaensen *et al.*, 2015). Assessment of status and trends is hampered by a lack of data, but the data which do exist show considerable variation across regions, countries and economy types, e.g., using the World Bank's country profiling and metrics (Chuhan-Pole *et al.*, 2013; HDRO, 2015; see Figure 1.15). Despite the data limitations, it is clear that tackling inequalities remains a considerable challenge for the future (World Bank, 2015a).

As indicated earlier, Africa is still largely agrarian and people living in rural areas experience most of the continent's poverty, both in terms of income and also through measures like the Multidimensional Poverty Index (MPI) (Christiaensen *et al.*, 2015; UNDP, 2015; World Economic Forum, 2015). The MPI itself exhibits wide variation across the continent, for example being >80% in Burkina Faso and Ethiopia and <10% in Egypt and Tunisia (UNDP, 2010, 2015). In Ethiopia, around 54% of the population living in urban households are affected by multidimensional poverty, but this reaches 96% when considering rural households. This urban-rural pattern is also seen in many other countries. While problems are greatest in rural areas, urbanisation itself certainly does not provide a route out of poverty for everyone, as is exemplified in cities all across Africa where the majority of urban settlements are associated with at least some unplanned, low-income settlements characterised by high rates of marginal economic activity (Arimah, 2011).

Much urban development in sub-Saharan Africa is informal, often characterised by a lack of basic services, poor housing, insecure tenure and overcrowding (Tibaijuka, 2007). Low-income urban settlements are likely to remain a core feature of urban Africa for some time to come and so the goals of conserving and enhancing biodiversity and ecosystem benefits must take this into account (UN Habitat 2014). Indeed, this makes the need for a serious consideration of urban ecosystem contributions all the greater, including how beneficial contributions can be yielded from informality, whether this is manifested in settlement forms or economic systems (Anderson *et al.*, 2013).

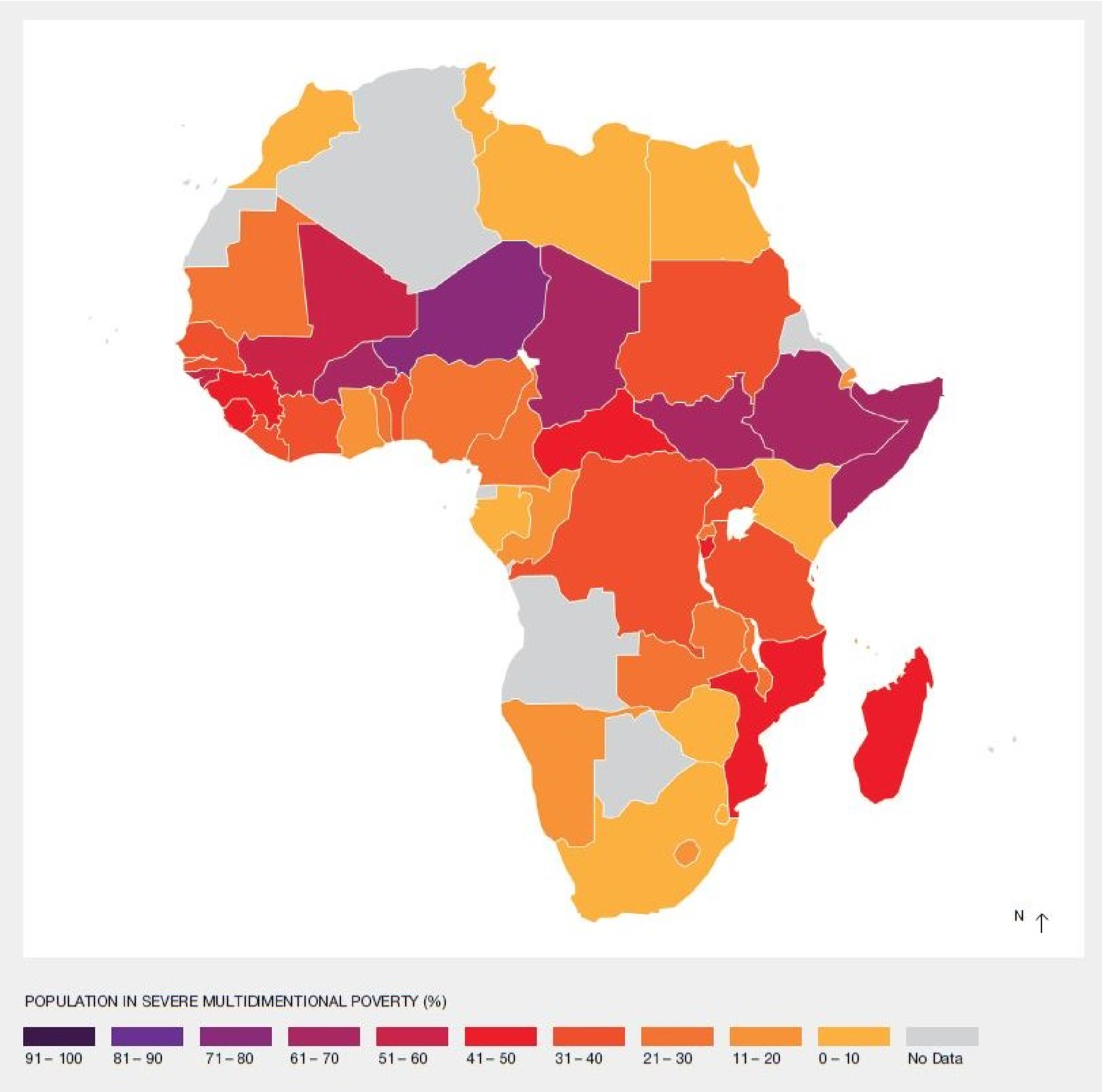


Figure 1.15: Levels of multidimensional poverty in Africa. Sources: methodology based on Alkire *et al.* (2010); Alkire *et al.* (2016); Alkire *et al.* (2017); data retrieved from http://hdr.undp.org/en/composite/MPI

Poverty dynamics matter to this assessment in a number of ways, but there are two main ways in which poverty dynamics are connected to biodiversity and nature's contributions and therefore provide important context for this assessment. Firstly, people experiencing poverty are particularly reliant on nature's contributions (Fisher *et al.*, 2013). Given the geographical distribution of poverty, reliance can be expected to be particularly strong in rural areas, although there is also emerging evidence of increased dependence in urban areas too (Fisher *et al.*, 2013; Lindley *et al.*, 2015). In South Africa, for example, it has been suggested that even in urban and peri-urban areas, poverty rates could be 5–10% higher without the ability for people to supplement incomes from ecosystem-based resources (Ward *et al.*, 2016). Material contributions from ecosystems offer an important 'safety net' through which people can maintain a good quality of life during times of need. This can be the case for food and fuel, but also for medicinal purposes, as is further explained in the next section. As a result, material contributions from ecosystems tend to be particularly valued. There is, however, also evidence that regulating contributions play a particularly important role in helping to improve the quality of life for the poor, for example as a means of accessing fresh air, clean water, shade and tranquillity. The impacts of meeting these needs, particularly when based on harvesting material contributions, can be felt in localised areas. This can result in over-exploitation, environmental degradation and the loss of biodiversity, even in critical biodiversity hotspots (Brown *et al.*, 2013). Sometimes degraded land is the only land which is available to the poor, leading to more marginal livelihoods and precarious living conditions, for example as a result of more extreme exposure to natural hazards (IPCC, 2012). This is a considerable issue given that as of 2010, some 22% of the entire population of sub-Saharan Africa was estimated to be living on land classed as degraded (UNDP, 2016).

The second way that poverty dynamics matter is that in order to lift people out of poverty, it is necessary to use material contributions from nature, i.e., to further tap into Africa's tremendous resources in order to provide the necessary infrastructure and materials to support economic transition (World Economic Forum, 2015). In addition to catalysing large-scale overexploitation, this may also lead to indirect drivers on biodiversity losses, as is explored in Chapter 4. Poverty, both in its own right and due to its connection to poor health and education, is considered to be one of the impediments to realising Africa's potential for future economic growth and security (World Economic Forum, 2015). In turn, economic transition—in a way which is mindful of the need for modes of production and consumption which protect ecosystems—is considered paramount to the ability to weather shocks and stresses on the continent and therefore to protect against poverty (UNDP, 2016). Poverty is also tied in with conflict and instability, acting as both a driver and outcome, but difficult to disentangle from other drivers, such as those associated with the political economy of natural resource exploitation.

Central to understanding the value of nature and the drivers of change on biodiversity and ecosystem contributions is an appreciation of who is more likely to experience poverty, the characteristics of poverty dynamics and the impacts of measures put in place to prevent or reduce poverty (an area also further explored in Chapter 6). Although a complex picture, there is evidence of the feminisation of poverty and associated characteristics such as literacy, access to information, power and influence (Chant, 2007). This is especially marked for some sub-groups—for example, widows, given that evidence suggests that the poverty rate is generally lower when the head of household is female, this is due to the high productivity of women in Africa. The only exception is found in Southern Africa since poverty rate amongst female-headed homes are higher (Christiaensen *et al.*, 2015; Beegle *et al.*, 2016). Older people are also disproportionately affected and, although there have been some improvements in intergenerational equality in Africa, this remains high. It is thus the social as well as the geographical distribution of poverty, which has implications for patterns in the demand for beneficial contributions and the potential for pressure and degradation. Poverty dynamics can be particularly marked at the level of individuals and households. Evidence from Kenya demonstrates that the most important set of factors determining a decline into poverty relate to the direct and indirect impacts of poor health (Kristjanson *et al.*, 2010). Health dynamics, trends, status and prospects together with their connections to nature and nature's contributions to a good quality of life are therefore integral to setting the scene for this assessment.

1.3.7.3 Human health and ecosystems

Good health is a central condition of a good quality of life and therefore the role of biodiversity and nature's contributions to health and well-being is critically important to understand. This is particularly so in Africa, where health challenges remain some of the most demanding in the world. The environment influences health through a range of physical, biological, social and psychosocial factors. Population health, the integrity of natural resources and development of a country are intertwined and interdependent. The final part of this section provides an outline of health issues in the African context and introduces some of the ways that nature and nature's contributions influence a good quality of life through human health. This inevitably includes discussion of some of nature's contributions to people, which require management in order to avoid having negative impacts.

Over the last decade, health outcomes in Africa have seen considerable improvement in many areas, including for some disease burdens and both childhood and adult mortality rates (WHO, 2014). This is in line with tremendous successes in global public health. For instance, there has been an estimated reduction in the incidence of malaria by 12.1% (9.7% low to 16.4% high) between 2000 and 2015, so that the Millennium Development Goal 6 "*to have halted and begun to reverse the incidence of malaria*" (Target 6C) has been achieved (WHO, 2016). There have also been improvements in responses to other important diseases, for example, through the Integrated Disease Surveillance and Response Strategy (WHO, 2014). Nevertheless, the lack of equal access to health and sanitary services is still a major threat for those affected by those epidemics which still, unfortunately, occur (e.g., ebola, yellow fever and dengue fever).

Between 1990 and 2012, all-cause mortality rates in children under 5 years old have almost halved, and maternal death rates reduced by 41% between 1990 and 2010. Some of the drivers of these changes include measures to tackle malnutrition and improve access to safe drinking water, both of which are strongly related to ecosystem-derived contributions. Although clearly important on human development and humanitarian grounds, these health improvements are also important for economic development, given that annual economic growth rates are estimated to rise by 0.4% in response to each 10% increase in life expectancy at birth (WHO, 2014). However, the 'ecological paradox' of degrading environmental conditions and improved health outcomes points to some of these successes potentially coming at the expense of future generations (Whitmee *et al.*, 2015).

There are a number of terms and conceptualisations, which are used to understand the factors which affect human health and well-being. For example, public health security is defined as *"the activities required, both proactive and reactive, to minimize vulnerability to acute public health events that endanger the collective health of national populations"* (WHO, 2007). This encompasses the emergence and spread of diseases caused by the contact between humans and nature (Eisenberg *et al.*, 2007). It also includes non-communicable disease, including the ways in which humans are subject to poor health as a result of exposure through air, water, soil and food pathways (see Chapter 4, section 4.2.2.5). Biodiversity and ecosystem contributions are also associated with other aspects of physical health like nutrition. Finally, emerging evidence strongly suggests that there are many wider influences with nature's contributions including for psychological and social well-being and for mental health. This is one of the areas in which synthesising ILK will be vital.

There are many factors explaining the emergence of infectious diseases, a major contribution of nature requiring effective management. Factors include environmental changes that have a natural origin (e.g., variations in rainfall, climate change) human-induced factors (e.g., deforestation, urbanisation, dam construction, practical food agricultural practices, trade, armed conflicts) and also the degradation or lack of availability of public health services (e.g., infrastructure and associated lack of vaccination programs). Nature's contributions are important for promoting and improving health. For example, there are many cases across Africa that demonstrate the role of forests in providing material contributions through subsistence benefits for human health. Increasing forest cover has been linked to improved dietary nutrition outcomes due to increased availability of material resources for sustenance (Johnson *et al.*, 2013, Ickowitz *et al.*, 2014, Rowland *et al.*, 2015). Moreover, wildlife consumed for food, although hosting potential for zoonotic pathogen transmission (Murray *et al.*, 2016), has also been linked to protecting human food security, and economic and nutritional well-being (Golden *et al.*, 2011; Brashares *et al.*, 2011; Fa *et al.*, 2015). The declines in fisheries, discussed in Section 1.3.4.1, have major implications for micronutrient supply. Chapter 4 (section 4.2.2.3.4) explores the impacts and illustrates how reliance on fish for nutrition and livelihood has gender and social dimensions, e.g., in the case of Senegal. At the same time that marine, freshwater and terrestrial ecosystems are coming under increasing pressure, many rural populations lack access to basic health, a situation that leads to poor health outcomes and restricts the population's ability for productivity.

The Libreville Declaration on Health and Environment in Africa (WHO-UNEP, 2008), signed by 52 African countries (organised by WHO and UNEP), is a platform to address the link between human health, wildlife and environmental health. The Population-Health-Environment approach is implemented in many countries in Africa as the way to integrate improvement of human health and environmental conservation in remote, ecologically rich ecosystems with the most dynamic human-environment systems.

Further, the emerging field of Planetary Health is also important to note here—a novel discipline within Global Health dedicated to understanding the ways in which human alteration of earth systems has led to significant human health impacts (Whitmee *et al.*, 2015). Poverty remains an important cause of poor health in much of sub-Saharan Africa. Some of this can be linked to negative outcomes resulting from the direct use of nature's material contributions to people. To give just one example, the use of charcoal and wood for domestic energy needs can lead to high pollution exposure burdens and

Box 1.7: Bio-prospecting: the case of Madagascar.

The International Cooperative Biodiversity Groups (ICBG) Program was established in 1992. Madagascar ICBG program had as its focus the three major goals of drug and agrochemical discovery, biodiversity conservation, and training and economic development. The program aims to integrate improvement of human health through drug discovery mostly from plants, the creation of incentives for conservation of biodiversity, and promotion of scientific research and sustainable economic activity that focuses on environment, health, equity and democracy. Due to the unique climate, geological structure and biodiversity of Madagascar, it provides a promising site for bio-prospecting unique biological samples. Beneficiaries, mostly local communities, were infrastructure, livelihood activities, training and capacity building.

Despite the signature in 2001 of the International Treaty on Plant Genetic Resource for Food and Agriculture (ITPGRFA), backed by the FAO, implementation at the national level has been slow (Prip *et al.*, 2015). Madagascar, for instance, has ratified the treaty in 2006, has ratified the Nagoya Protocol on ABS in 2014 and both ITPGRFA and NP/ABS have each drafted laws for the implementation of these international instruments at the national level. In June 2016, regulations were drafted as interim measures but there is still no formal policy on bio-prospecting or access and benefit-sharing (ABS).

associated respiratory illness and mortality, especially in young children (Bailis *et al.*, 2005; Lim *et al.*, 2012). Issues associated with air pollution are discussed in more detail in Chapter 4.

Flooding and drought must also be considered, as well as their interrelation with uncontrolled urbanisation and the related obstruction of previous flows in the ecology of urban and peri-urban systems. Ecosystem changes, including deforestation and climate-related changes, influence waterborne as well as vector-borne diseases. If not sufficiently addressed, these diseases can eventually result in pandemic crises. Many water-borne and vector-borne diseases belong to a group referred to as Neglected Tropical Diseases. As the last Ebola crisis showed, there are considerable international threats around neglected tropical diseases.

One specific example of how anthropogenic drivers acting on intact landscapes have driven a proliferation of emerging infectious diseases is the increasing demand for bushmeat for food. Further, global transportation of people, wildlife and livestock, as well as blood-to-blood contact during the hunting and butchering of bushmeat increase opportunities for cross-species disease transmission in Africa such as Severe Acute Respiratory Syndrome, monkeypox, Ebola and HIV/AIDS. The Cost-effectiveness analysis conducted by WHO of environmental health interventions demonstrated that the impact of environmental health management is highly uncertain due to methodological difficulties, the lack of reliable data and the lack of data which connects to stakeholder needs (Edejer *et al.*, 2003).

In Africa, the use of medicinal plants has always been a fundamental component of traditional healthcare systems, and it is perhaps the oldest and the most varied of all therapeutic systems. This knowledge has been validated through its transmission over many generations. In many developing countries, it is believed that traditional medicine is still the main source of health care for about 80% of the population due to its cultural acceptability, affordability and accessibility (Elujoba *et al.*, 2005). Prescription of medicinal plants by traditional healers in many parts of rural Africa is the most easily accessible and affordable health resource available to local communities and at times the only therapy that exists. Studies suggest that there are 5,400 documented medicinal plants in Africa (Moyo *et al.*, 2015). Nonetheless, there is still a paucity of up-to-date and comprehensive databases of plants with known and potential medicinal properties for the African continent. This is in part due to the highly localised nature of indigenous knowledge bases.

Due to the importance of traditional health systems and related ecosystem contributions in Africa, Chapter 2 further extends the discussion introduced here. It is clear that sustainable management of traditional medicinal plant resources is important, not only due to their value as a potential source of new drugs, but also due to reliance on traditional medicinal plants for health and in some cases for income. Examples from Sahelian countries show how wild plants play important social, cultural, aesthetic and ethical roles for rural communities, as local people depend on them for food, traditional medicine, construction, handicrafts, cosmetics, forage and revenues (Dembélé *et al.*, 2015). A recent IPBES report (Roué *et al.*, 2016) shows that 72% of Egypt's desert systems species were used for medicinal purposes, and that they also provided an income for local communities. Their use is not only due to cost but also due to perceptions of their higher effectiveness and relative ease of access (from herbal shops and directly from the environment) (Roué *et al.*, 2016). With few exceptions, traditional medicinal plants are collected from the wild as barks, roots and whole plants. Although reliance on traditional medicinal plants may decline in the long-term as alternative healthcare facilities become available, increasing demand for popular herbal medicines is expected in the foreseeable future.

1.3.8 Governance, tenure, security and trade

The way people hold, use and manage their land and natural resources; the way they produce food, consume goods, and manage their wastes and knowledge systems; their health as well as their cultures, freedoms and security-condition, and are conditioned by prevailing systems of governance. There are numerous and varied definitions of governance. In the context of this assessment, we define governance as the diverse and plural modes and processes of making decisions on society and the environment and acting upon them (see Chapter 6). This highlights some of the factors and frame conditions through which natural endowments are used, food and goods produced, and diverse socio-environmental outcomes realised (see Chapter 2). Governance is thus central to all biodiversity and ecosystem services issues, and particularly to the issues discussed across this section. Its definition can be applied to broad cross-sections of the human-ecological complex or to specific areas, as in biodiversity governance, landscape governance, tenure governance or climate governance.

Partly for editorial reasons, this subsection emphasises the specific interrelations linking governance to tenure, security and trade. This happens in extremely diverse and fundamental ways. The management of natural resources, the impacts of armed conflicts on biodiversity, and conflicts over disputed natural resources are some of the issues addressed here.

1.3.8.1 Environmental governance in Africa

There is a diversity of governance frameworks. Most emphasise one or both components of governance as a structure of normative and ethical principles (Figure 1.16). For instance, many UN agencies have adopted variants of UNDP's five principles of "good" governance: (1) participation and voice, (2) accountability (including transparency), (3) equity (including rule of law), (4) direction (relating to strategic vision), and performance (including responsiveness, effectiveness and efficiency) (Buchanan-Smith *et al.*, 2013). However, there is a bias in the literature, which tends to reflect predominantly normative and hierarchical views of governance. For instance, UNESCO-IHE (Buchanan-Smith *et al.*, 2013) defines governance as the process of taking care of public interests through leading, ruling, planning and managing, controlling, and correcting (enforcing and sanctioning) organisational resources. This definition is more top-down and gives primacy to a leading, controlling agency. Other frameworks are more neutral in engaging the responsibility of a multiplicity of influential agents (see also Chapter 6).

This assessment is more in tune with that second trend. It considers that governance happens at multiple scales, involves multiple parties, not just governments, and integrate dimensions related to (i) social choices and strategic direction, (ii) norms and performance (capability, transparency, legality), and (iii) social justice (voice, equity, legitimacy). Though Figure 1.16 does not show it, each principle is clustered with functionally related indicators. For instance, transparency is functionally related to accountability and responsibility and is sometimes interchangeable with them. The same is true, for instance, of equity, fairness and natural justice; legality, rule of law and justice (judiciary); capabilities, performance and responsiveness. It can be useful to think of those clusters as bundles of governance principles or governance norms associated with sets of governance indicators.

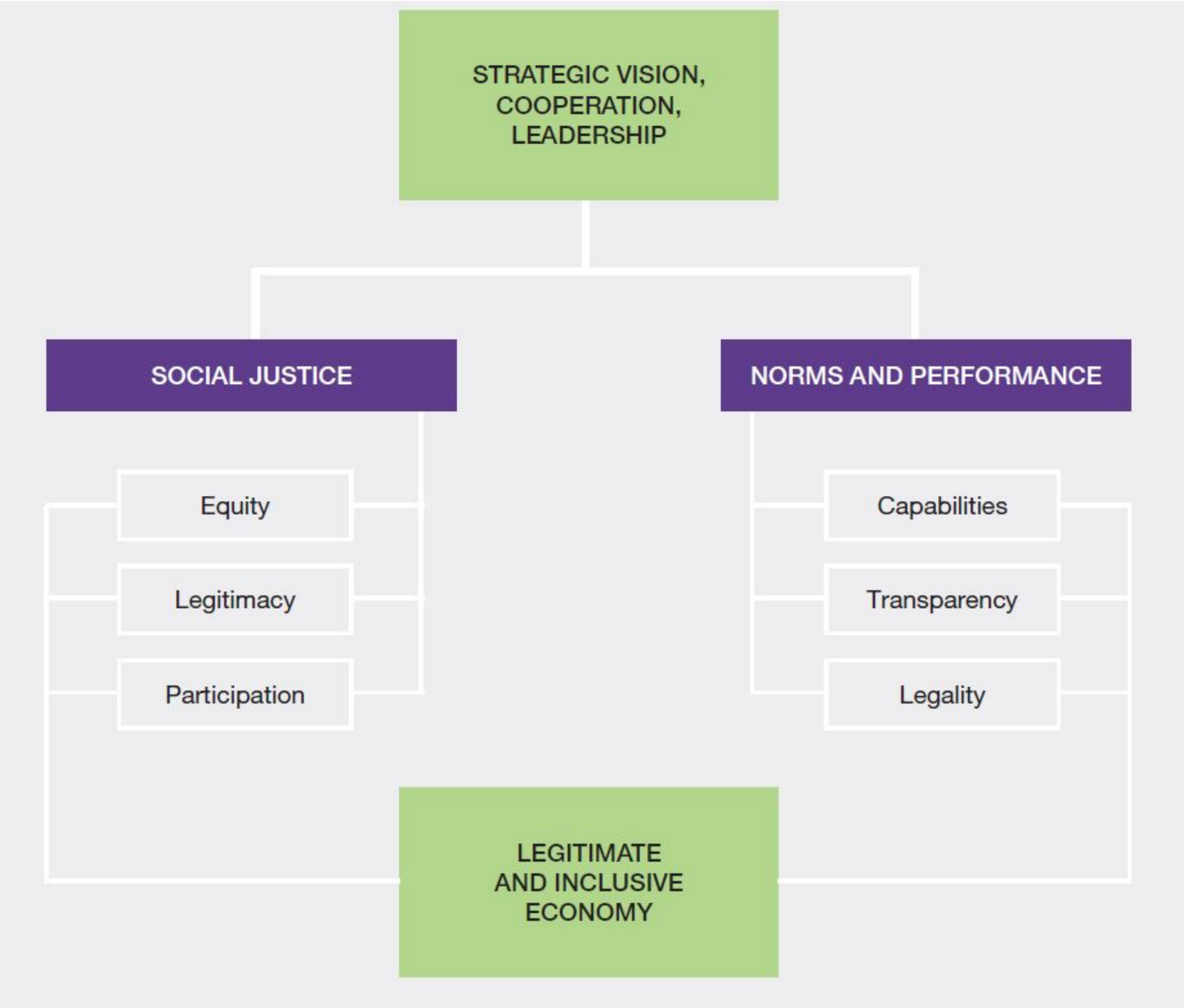


Figure 1.16: Structure of governance principles. The economy is a key domain out of which the constitutive values of governance cannot really be expressed in the society. Source: Diaw *et al.* (2016).

In a recent paper on Earth System Governance for Africa (Habtezion *et al.*, 2015), 13 scientists, mostly African, make the case that traditional environmental governance "do not adequately address the gamut of human-natural system interactions within the context of the complex bio-geophysical cycles and processes of the planet". They argue that modern and traditional governance systems in Africa have complex relations with global change dynamics and that attention must be paid to the resulting system drivers and teleconnections. Though, perhaps not at the scales and scopes of bio-geophysical integration promoted by the Earth System Governance framework, these questions have actually been extensive objects of research and policy analyses in Africa. A small cross-section is considered below in relation to the lessons that have been drawn from natural resources management decentralisation, participation, biodiversity governance, and integrated landscape management.

1.3.8.1.1 The decentralisation of Natural Resource Management

Very little is known and has been written about pre-colonial conservation practices in the region. A rather misplaced belief is that low population densities, 'unsophisticated' agricultural and hunting practices, and 'immobile populations' meant that ecological conservation was built into the routine economic, social and religious activities of the era. Consequently, pre-colonial societies did not need to develop sophisticated conservation mechanisms. The reality is very different. Ample evidence exists of settlements consolidated with high population densities (Murombedzi, 2003), such as in the Niger Delta and Bambara City States, in Great Zimbabwe, Kanem Bornou and the earlier empires of Ghana, Mali and Songhaï, for instance (Diaw, 1985). Agricultural and resource extraction activities were finely adapted to the requirements of specific resources and ecosystems, while the societies themselves developed sophisticated mechanisms to regulate resource use. However, much evidence of pre-colonial conservation practice has been displaced by colonial conservation practices. In Southern Africa, a significant number of contemporary protected areas were already protected under pre-colonial regimes. Examples of such pre-colonial conservation areas include Central Kalahari Game Reserve, Moremi Game Reserve and Chief's Island in Botswana; Mavhuradonha, Matopos, and Gonarezhou National Parks in Zimbabwe; Tsidilo Hills, Mamili National Park, and Salambala in Namibia; and Hluhluwe-iMfolozi Park in South Africa. However, the imposition of colonial conservation regimes on these landscapes led to conscious efforts to obliterate these pre-existing land-uses and their long-term impacts (Murombedzi, 2003; Adams, 2003).

Decentralisation in Africa started in British colonies in the 1950s. Local bodies with limited powers were then created, although newly independent governments actively seeking to reinforce nationalism and allegiance to the central State, later suppressed them in the 1960s. By contrast, Francophone countries such as Mali, Burkina Faso and Senegal started decentralisation after independence in 1960. They saw it in a different light, as a way to construct the nation-state by extending its reach through local governments (Diaw, 2010). Senegal went as far as establishing rural councils in 1972 (Jacob *et al.*, 1997). Overall, however, command and control approaches and forms of “decentralised despotism” (Mamdani, 1996) dominated the governance field at the time (Manor, 1999). The 1990 Arusha Declaration and the African Charter for Popular Participation in Development and Transformation played a key role in raising African political awareness of this “over-centralisation of power” and its “impediment to the effective participation of the overwhelming majority” (UNECA, 2010). The full growth of decentralisation policies in Africa took place in the 1980s and 1990s. This was a global movement, closely associated with structural adjustment policies; land and fiscal reforms; and the progression of electoral democratic frames; and it took many forms in Africa (Diaw, 2010). Devolution to rural councils and urban and rural municipalities started in countries such as Mali, Niger and Burkina Faso in the aftermath of the democratic transitions of the 1990s. Mozambique, Ghana, Ethiopia, South Africa, Kenya, Uganda, DRC, and several other countries, now have decentralisation enshrined in their laws or constitutions, although often not fully effective.

In spite of diverse and elaborate typologies, a loose consensus had emerged by the late 1990s around two major forms of decentralisation: (1) deconcentration or administrative decentralisation, marked by the dispersal of state powers from higher to lower levels of administration; (2) devolution, when decision-making authority is transferred from central government to local groups and institutions. These concepts and a host of related variants where applied to dozens of reforms of the state and natural resource sectors in the developing world, particularly agriculture, forests, fisheries, water management, health, and biodiversity conservation. Natural resource management decentralisation was, in this way, the key channel by which citizens and communities became involved in the governance of biodiversity and ecosystem services in Africa. Participatory natural resource management started in Africa at the end of the 1980s in an effort to empower local resource users. Examples include ‘gestion de terroir’, local conventions, community-based natural resource management, community forestry, and participatory forest management (Hilhorst, 2010). This movement is still evolving today to include community wildlife management schemes, integrated conservation development projects, integrated water resource management, marine protected areas and Integrated Landscape Management (ILM), the most recent initiative.

Box 1.8: Community-Based Natural Resource Management (CBNRM)

CBNRM initiatives facilitated local agreements on regulating resource use in countries such as Mali and in Madagascar where they were known as GELOSE. In Tanzania, which is described as one of the most advanced community forestry jurisdictions in Africa (Wily, 1997, 2000; Blomley, 2006), 'village governments' have significant powers to receive, raise and disburse funds based on local plans and to enact bylaws under the Village Land Act of 1999. In Niger and Ethiopia, local governments can also enact by-laws on land-use and even register common pool resources in their name. In some countries (e.g., Rwanda, Burkina Faso, Benin), local government is responsible for the management of small-scale irrigation schemes and drained wetlands in valley bottoms (Hilhorst, 2010). The Gambia offers a rare case of self-initiated CBNRM, later co-opted, after eight years, by the official community forest program (Diaw, 2009). In Central Africa this movement started in the mid-1990s with the 1994 forestry law in Cameroon, followed by most other Congo Basin countries within a decade. This included community forestry reform, as well as fiscal decentralisation of forest revenues and the establishment of municipal forests and community hunting zones and committees (e.g., Logo, 2003; Nelson *et al.*, 2003; Oyono, 2005; Oyono *et al.*, 2007;). CAMPFIRE in Zimbabwe was actually the pioneer in 1989 of African community wildlife management schemes, which were later taken on by a number of other countries, including Cameroon, Rwanda and Uganda (Matose, 1997; Mandondo, 2000; Prabhu *et al.*, 2001). For their part, Burkina Faso, Ghana, Kenya, and Senegal developed advanced legislative and regulatory mechanisms for fiscal and financial decentralization. But it is noted that local governments have had limited capacity in practice due to the inadequacy of financial transfers from the central government and weak local revenue-raising capacity (Chambas *et al.*, 2012). Other natural resource management schemes also had problems, such as central retention of powers, weak local participation and accountability, conflicts with customary tenure and elite capture (Diaw, 2010). It was also noted that governments continue to appropriate valuable local commonage and lease these lands to investors for farming, logging, mining, ecotourism and carbon credits compensation schemes (Wily, 2008). Decentralisation of water management also took place in many countries, essentially under the form of integrated water resource management. Most Southern African countries have enacted or amended their water laws and policies and restructured their institutional and governance frameworks in that line over the last 20 years or so. But it is also noted that actual devolution to local institutions and local water stakeholders, which often have a better knowledge of the catchment functioning, has been unequal and wanting. In South Africa and Mozambique several years after the launch of the new water policy, the vast majority of catchment management agencies and water administration entities were not operational, while many water user associations were struggling to find their place in the water management schemes (Farolfi, 2010).

1.3.8.1.2 The historicity and evolution of protected areas

Historically, protected areas have been the main sites of biodiversity conservation in Africa. Sabie (Kruger National Park) in South Africa and Amboseli in Kenya were established as early as 1892 and 1899 respectively. Other reserves were established in the 1920s and 1930s, often to be re-gazetted as national parks after the Second World War or after independence (Diaw, 2014). This fits the global post-war growth of protected areas, particularly after 1960. By the time of the 2003 World Parks Congress in Durban, which was instrumental in identifying governance as "central to the conservation of protected areas" (WCPA, 2003; Borrini-Feyerabend *et al.*, 2004), Protected areas had grown from less than 10,000 in 1950 to more than 100,000 sites around the world (Diaw, 2010). They now cover over 15% of the world's terrestrial areas and inland waters and 3% of the oceans (Belle *et al.*, 2015).

Through CBD Aichi Biodiversity Target 11, governments worldwide have pledged to protect at least 17% of terrestrial areas and inland water and 10% of coastal and marine areas by 2020.

Using data from the World Database on Protected Areas, augmented by records from the Indigenous and Community Conserved Areas, registry and other additional data, Belle *et al.*, (2015) found that protected areas, for which spatial data was available, cover 13.4% of sub-Saharan Africa's land area and 2.6% of the marine area. Across the four IUCN governance categories, they found that state governance (1,273,123 km^2) represents 35.6% of the total protected area coverage (or 78% of the known governance types), community governance (232,277 km^2) 6.5% of the total (or 14.2% of the known types), shared governance (117,452 km^2) 3.3% (or 7.2%), and private governance 0.3% (or 0.7%). Governance types were not recorded for 54.3% of the protected areas in sub-Saharan Africa (see Figures 1.17 and 1.18 for representation of more recent WDPA data).

From their origin and following a global pattern, protected areas in Africa were established under tight government control and in ways that excluded local people from their management and use. This reflected centralised concepts of State as well as the perception that it was the only way to preserve critical habitats and species representing an exceptional national heritage. These restrictive policies had severe impacts on local people, including cases of forced displacements, and were a continuous source of tensions and conflicts around protected areas (Brockington, 2002; Cernea *et al.*, 2003; Schmidt-Soltau, 2003; Tiani *et al.*, 2006; Diaw *et al.*, 2010).

Beyond terrestrial biomes, such processes also occurred in marine environments. Belle *et al.* (2015) cite the case of the South African Hangberg marine protected area, established in 1934, where 70 years of dispossession of local fishing rights "resulted in an impoverished community, a thriving informal or illegal fishery and an eroded sense of legitimacy toward the state". State-driven marine protected area planning in Mozambique is reported to have similarly harmed communities and provoked ambivalence towards marine protected areas.

Privately protected areas were the first alternative governance type to emerge in the 1950s (Langholz *et al.*, 2004). They most often take the form of private game ranches, private nature reserves and private conservancies, particularly in eastern- and southern Africa where many natural features and landscapes are favourable to developing markets for wildlife and where land tenure regimes and legislation favour private ownership of such lands. Only after the 1980s did non-state governed protected areas start to gain prominence, making up nearly half of protected areas gazetted after 2000 and the great majority after 2010. As illustrated in Figure 1.18, such governance is still very weakly represented in most of Africa.

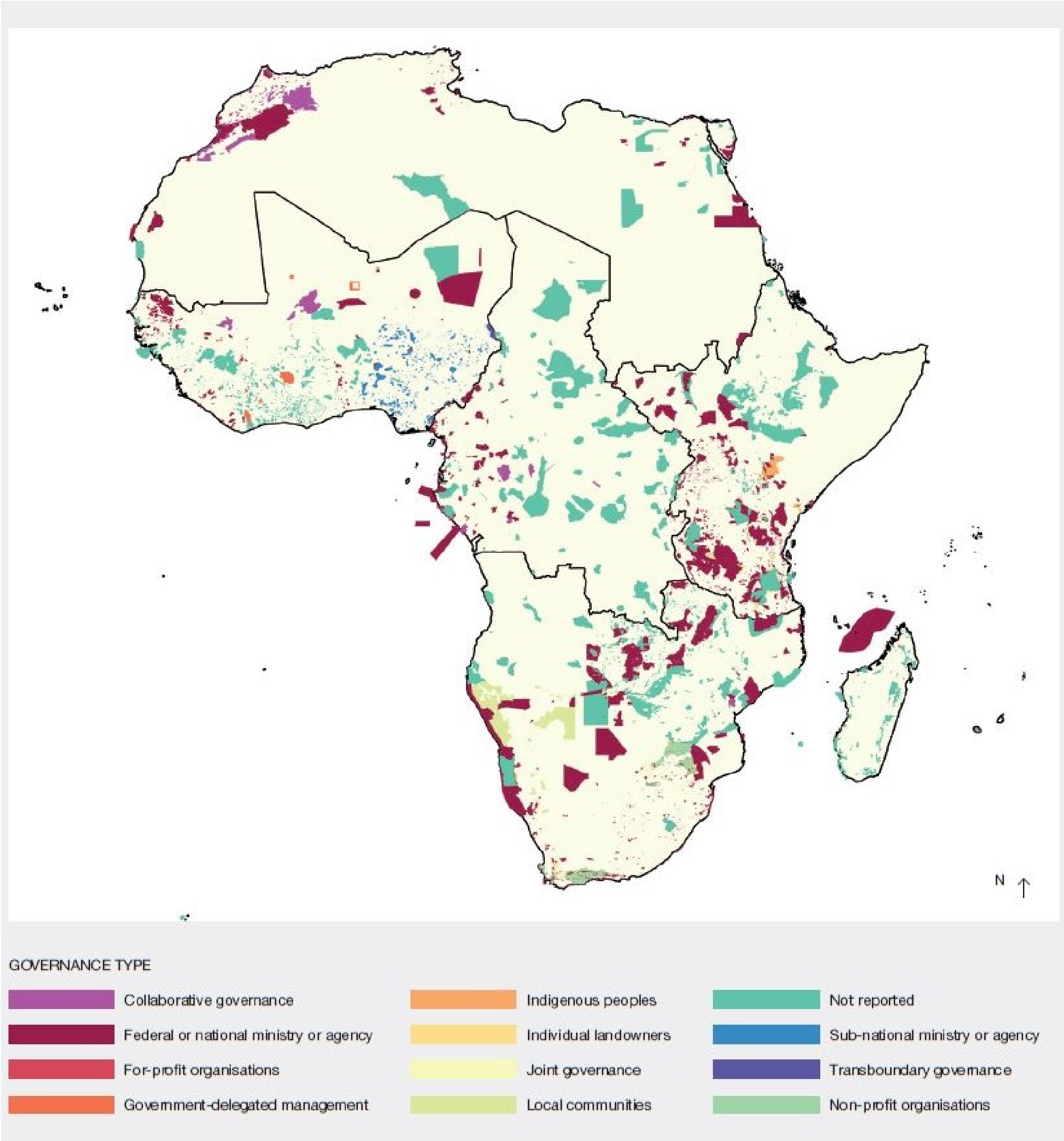


Figure 1.17: Protected areas by governance types in Africa. Source: data from UNEP-WCMC *et al.* (2017).

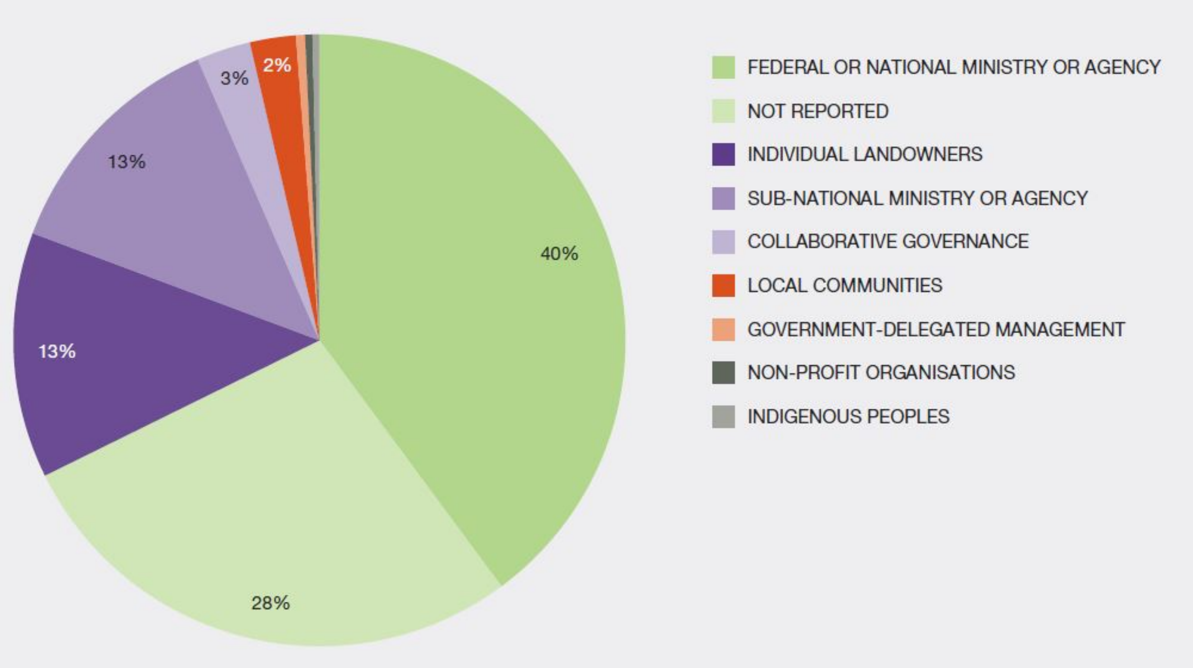


Figure 1.18: Percentage of protected areas under different governance types in Africa. Source: data from UNEP-WCMC *et al.* (2017).

1.3.8.1.3 Integrated Landscape Management (ILM)

ILM has recently emerged as a rallying point for moving beyond land-use conflicts and single-sector policy silos to address the values and interests of stakeholders across land-uses and policy domains. Landscape approaches have been around for several decades but the growing consensus that they now enjoy globally and in Africa is recent; there are now more than 500 ILM initiatives around the world, 87 of them in Africa (Scherr *et al.*, 2013; Milder *et al.*, 2014; LPFN, 2015). "Integrated landscape management encompasses agriculture, ecosystem services, biodiversity, aesthetic landscape value, cultural identity and recreational values as well as human settlements and resource extraction industries. Networks are emerging, such as International Landcare that support dozens of locally-organised landscape initiatives in Asia and Africa, and the international Model Forest Network that supports long-term multi-stakeholder initiatives in 58 landscapes in the Americas, Africa, Asia and Europe" (Scherr, 2014).

Examples include multi-objective landscape restoration in Rwanda, the Great Green Wall initiative in the Sahel, ILM in Ethiopia and Kenya, climate-smart landscape for certified cocoa in Ghana, and Model Forest landscapes in Cameroon, DRC, Central African Republic, Congo, Rwanda, Morocco, Tunisia and Algeria (Milder *et al.*, 2014; Diaw, 2015; Kusters, 2015). Inclusive global and regional platforms have been formed to support this process, particularly the Landscape for People, Food and Nature, the Global Partnership for Forest Landscape Restoration and the Global Landscape Forum, The African Landscape Restoration Initiative (AFR100), and the African Union's Resilient Landscape Initiative. This trend is comforted by the African Landscape Action Plan, endorsed by the AU and several of its programs and supported by Landscape for People, Food and Nature. All these developments suggest that landscapes will play an increasingly important role in African countries attempts to reconcile their conservation and restoration interests with the growing demand for demand for food, consumer goods and multiple ecosystem benefits in the region.

1.3.8.2 Land tenure and tenure governance

Land tenure is an all-encompassing theme in environmental governance (see also Chapter 6). Diaw (2009) makes the case that at the heart of land and governance issues in Africa is the coexistence of, and unresolved tension between blood rights (*jus sanguinis*) and territorially based civil rights (*jus soli*). These are the two predominant forms of government in history (Morgan, 1877). In blood rights, government is exerted through descent groups, while territorially based civil rights are founded on political citizenship and membership in a territory. Thus, community and citizenship continue to coexist in tension as distinct sources of popular legitimacy in Africa. Variants of this tension still exist in other regions, including in the definition of citizenship in the West. The fundamental characteristic of tenure, as an expression of this tension in Africa, is legal pluralism, the continued coexistence of customary tenure alongside statutory tenure regimes inherited from British, French, Portuguese and Spanish colonialism.

1.3.8.2.1 The persistence of customary tenure

Colonialism introduced new dimensions of land ownership that denied pre-existing communal land rights in order to impose the sovereignty of the colonial state and the essential supremacy of private property and title (Mamdani, 1996; Berry, 1993). According to Diaw *et al.*, (1998) a major paradox of the African land tenure nationalism in the 1960s and 1970s is its origin in colonial tenure policies. In Francophone Africa, the national domain laws made the state the manager or guardian (e.g., Côte d’Ivoire, Senegal, Mali, former Haute Volta, Madagascar, Cameroon) or the owner (e.g., Guinea, Mauritania, former Zaïre) of the national estate. They sought to reduce the communal bases of African tenure in order to “detribalize” the system (Melone, 1972) and build the nation-state. A few countries, such as Kenya, and to a lesser extent, Uganda, developed strong privatisation programs while others, such as Tanzania and Ethiopia, attempted to replace customary tenure with sweeping villagization and land-to-the-tiller reforms (Bruce *et al.*, 1998). Other countries, such as Ghana and Sierra Leone, did recognise customary authority through a dual system of land administration under state guardianship. Overall, a dual, unequal and hierarchical system of land tenure was inherited, with freehold and leasehold being treated as superior to customary land rights (Shivji *et al.*, 1998).

As a whole, these policies failed to achieve the anticipated dissolution of customary tenure (Diaw, 2005). Rather, tenure tradition continues to coevolve with statutory laws, getting more complex as they intertwine over time, eroding in some places, emerging anew in others, and eluding both theoretical predictions and reform planners. Until the late 1990s, customary or community-based tenure was found to be the ‘de facto dominant tenure type’ in virtually all of sub-Saharan Africa with the exception of Cape Verde, South Africa and Namibia (Bruce *et al.*, 1998). In Kenya, it was found to be co-dominant with private ownership, despite one of the most aggressive, long-standing privatisation program on the continent. The same was true of Senegal, whose privatisation scheme went as far back as the 1830s (Diaw *et al.*, 1998). The extraordinary resilience of customary tenure is a direct consequence of its “embedded” nature, that is, the way it nests private rights into the commons and collective property, and then into marriage and descent (Diaw, 1997, 2005; Agbosu, 2000). Failure to understand this blocked many attempts to change customary tenure, and the resulting legal pluralism—“the presence in a social field of more than one legal order” (Griffiths, 1986) still endures.

1.3.8.2.2 Africa's adaptations to legal pluralism

Replacement policies have now given way to "recognition that land policies and laws must build on local practice, and that there is no 'blueprint' approach that can be successfully applied to different contexts and cultures" (Buchanan-Smith *et al.*, 2013). The African adaptation to legal pluralism took many forms, alongside continuous exercise by the State of its sovereignty over the national domain through the granting of land-related concessions, the facilitation of private land acquisition schemes or occasional expropriation of communal lands for purpose of public interest. Hilhorst, (2010) notes "a general shift towards some form of legal recognition of customary rights", as countries review their land policies and legislation to secure smallholders' rights, while making land available to investors and encouraging productive land-use. Buchanan-Smith *et al.* (2013) cite the Kenya Land Policy of 2007 as an interesting example of how statutory frameworks and legislation can recognise and protect customary rights. The policy also makes unusual provision to secure pastoralist land rights and livelihoods.

In order to deal with critical land administration issues, a number of countries have developed systems for the inventory and registration of local land rights. This is the case in Madagascar, as well as Ivory Coast, Benin and Burkina Faso with their '*plans fonciers ruraux*' and Burundi with the '*guichet foncier*'. All countries established local committees for rights inventories and to mark boundaries, register land, record transactions, safeguard deeds and mediate land conflicts. In most countries, customary authorities are encouraged to become members or to collaborate with these committees. Examples of such committees are the Land Administration Committee (LAC) in Ethiopia at the *kebele* (ward) level, the *commissions foncières* at the village level in Niger, the *commission de reconnaissance locale* in Madagascar and the land adjudication committees (cell level land committees and sector level land committees) in Rwanda. Ensuring that women are part of these committees has proven to be important for equity in Ethiopia (Hilhorst, 2010). Land administration approaches also vary only slightly from one country to another. In Burkina Faso, there is an inventory of prevailing rights, followed by registration. Ethiopia and Niger follow registration with the issuance of a certificate, while Rwanda adds a light form of surveying. Some countries only register at the request of individuals (e.g., Madagascar, Burundi), communities (e.g., Benin, Niger) or if suggested by local governments (Niger). Land information archives are kept locally at the village (e.g., Tanzania, Malawi), or local government level (e.g., Burkina Faso, Ethiopia) or may be fed into a nationwide database (e.g., Madagascar). Hilhorst (2010) notes, however, that the linkage "between these 'new land policies' and existing legislation concerning forests, grazing lands, fisheries and other natural resources, or legislation related to 'community-based natural resource management', is often missing". It may be up to local governments or integrated platforms such as the ones found in ILM to bring together these various strands of legislation, policy and practice.

1.3.8.3 Policy frameworks and guidelines on tenure governance

Today, land tenure and land governance remain challenging areas of work throughout the continent. For instance, since the early 2000's, Africa has been experiencing an unprecedented wave of large-scale land acquisitions, the largest on the planet (Carmody, 2011; UNECA, 2013; Nolte *et al.*, 2016). Countries such as South Sudan, Sudan, DRC, Liberia and Guinea are at the forefront of these developments spurred largely by foreign investments. To date, Africa has a recorded a total of 422 operations, expected to cover some 35 million hectares for a range of purposes related to food and non-food agricultural commodities, such as biofuels and livestock. It has been pointed out that these developments could result in the destruction of vast natural habitats across Africa and the depletion of biodiversity (Lee *et al.*, 2011; Senelwa *et al.*, 2012) as well as the dislocation of the rights of local communities (Oyono, 2013). Thus, a number of regional and international frameworks and guidelines have emerged over time to help deal with issues such as state and foreign investments, land grabbing, agricultural growth model, or indigenous people and local communities' rights.

The Land Policy Initiative, jointly established in 2006 by the AU Commission, the United Nations Economic Commission for Africa and the African Development Bank, has been instrumental in producing a Framework and Guidelines on Land Policy in Africa, which was adopted in 2009 by African Heads of State and Government through an AU Declaration on Land Issues and Challenges in Africa. In 2006, a process of consultation and negotiation involving 190 governments was also begun at Porto Alegre, Brazil, with civil society and private sector groups. This ultimately led, on 11 May 2012, to the adoption of the VGGT—the Voluntary Guidelines on the Responsible Governance of Tenure for land, fisheries and forests in the context of national food security—by the Committee on World Food Security. These frameworks, supplemented by a host of other guidelines, for example, on the Right to Food, Responsible Agricultural Investments, Transparency and Disclosure, and Large-scale Land Acquisitions and Investments, hold much in common. They emphasise inclusiveness, participation and a multi-sector approach to land governance, reflecting lessons learnt from decades of work on land tenure and natural resources governance (Hall *et al.*, 2016).

The UK Department for International Development's LEGEND (Land: Enhancing Governance for Economic Development) project very recently published a State of the Debate Report on the implementation of the VGGT (Hall *et al.*, 2016). The report notes the similarity of principles and complementarities between existing frameworks and the World Bank's land governance analysis framework. It also identified several initiatives operating at pan African and country levels, including the New Partnership for Africa's Development (NEPAD)/Comprehensive Africa Agriculture Development Programme's joint Land Governance Program supported by the EU and a few initiatives using the World Bank's set of 27 land indicators to assess progress towards VGGT compliance. This framework "has now been implemented in 33 countries, with another 11 currently using it" (Hall *et al.*, 2016). The report also notes the land partnerships established in 2013 by G7 countries in Africa with the purpose of accelerating implementation of the VGGT in eight pilot countries: Burkina Faso, Ethiopia, Niger, Nigeria, Senegal, Sierra Leone, South Sudan and Tanzania.

Finally, a number of international and national NGOs are involved in separate campaigns for land rights and land justice. Some have built relationships with multinational companies and assist them in operationalising the VGGT in their business operations and supply chains. Others work with communities to protect and defend customary land rights, and cover topics such as mapping and boundary agreement, community land governance rules and protecting land in investment negotiations. For instance, Namati, a global movement of grassroots legal advocates, with partners in Liberia, Mozambique and Uganda, works on the impacts of the registration of community land rights. As an alternative to individual titling, community registration of rights presents a model that is arguably more suited to forms of customary tenure (Hall *et al.*, 2016).

1.3.8.4 Conflicts, peace and security

Allocation, distribution and access to ecosystems services have been shown to play a key role in a broad range of different types of conflicts in Africa. Tenure, governance and poverty have played key roles in conflicts that spilt into devastating civil wars and armed confrontations in many parts of the continent. Collier *et al.*'s (2000) econometric model of civil war identifies two possible motives for such an aforementioned occurrence: greed or *loot-seeking*, and grievance or *justice-seeking*. Applying it to the African situation, they found that, on average over the period 1965–99, Africa had an incidence of conflict similar to that in other developing regions. The continent had, however, a very different structure of risk, essentially because of deteriorating economic performances. Their analysis suggests that the rising trend of African conflicts was not due to deep problems in the African social structure but to an atypically poor economic performance. Other contributing factors included the historical context, the existence of grievances and of large groups willing to engage in rebellion, and the availability of finance to meet payroll and buy weapons. Although Collier's greed-based theory has been criticised for reductionism (Sambanis, 2004; Bensted, 2011), such factors were indeed prominent, for instance, in the Sierra Leone rebellion and civil war.

The interrelationship between biodiversity and ecosystem services, natural resources and conflict is dynamic and multifaceted. Not all conflicts are violent and not all violent conflicts are carried out with weapons. Similarly, security does not necessarily require armed intervention. Therefore, in discussing conflict and security in the context of BES governance, this analysis takes into account three critical levels that need to be differentiated: (i) causal dynamics in the rise of conflicts that can spill over into violence and armed confrontation, including climate change; (ii) the impact of conflicts on biodiversity and ecosystem services and socioeconomic conditions; (iii) the governance configurations needed to facilitate security and peace-building.

1.3.8.4.1 The rise of conflict and violent confrontation

The drive to access natural resources may be a major cause of direct conflict, and yet it is entwined with the complex interactions of other factors, such as ethnic identity, tensions, and other historical, social, economic, legal and political factors operating at local, national and international levels (Onyige, 2011; also see Chapter 4). When not equally and evenly distributed, the allocation and distribution of, and access to ecosystems services and natural resources build up at multiple levels for a broad field of grievance and greed to gain sufficient ground to transition to armed confrontation. The new security risk driven by climate change further complicates the problem by bringing about environmental and human security variables not taken into account by Collier *et al.*'s (2000) model, which posits that armed conflicts are caused by combatants' desire for self-enrichment.

A recent study (Larcom *et al.*, 2016) has shown that "local institutions inherited from the pre-colonial era continue to play an important role in natural resource governance in Africa". Land disputes around customary land rights have been a causal factor in the majority of conflicts in Africa since the 1990s. Wily (2009) reports that only in three out of 30-plus conflicts were customary land rights disputes, not "a fundamental grievance driving people to war and emerging out of war as a concrete target of remedy". Unruh (2008) shows that land issues were a significant source of the overall conflict in Sierra Leone. The debilitation of customary and formal land institutions, as mentioned earlier, was a major cause of rural marginalisation, disenfranchisement, and poverty, all of which led to pronounced discontent. Large numbers of poor and unstable rural youth were 'spun off' from village society because of control exercised by village elders over land and marriage". In some areas of the country, land problems were so acute that joining the rebels sometimes led to the opportunity to take lands by force. In fact, land problems contributed to the eruption or exacerbation of conflicts in all the Mano River countries (Sierra Leone, Guinea, and Liberia) as well as in Côte d'Ivoire. "The chieftaincy system was one of the primary contributors to the war due to longstanding and common abuses, particularly regarding land issues. As a result, some of the worst violence was focused on certain leadership elements in the customary system, and many chiefs were targeted by the Revolutionary United Front and fled for the safety of Freetown, the capital, or abroad".

In a 2012 paper (Adano *et al.*, 2012), the Institute for Security Studies elaborates on a wide range of conditions that make climate change a major potential security threat for Africa. This owes in particular to a combination of severe climate-related impacts on economies that are highly climate-dependent and countries that currently have the least capacity to adapt. The Institute for Security Studies notes that spatial and temporal changes in rainfall patterns and frequent droughts make the survivability of African pastoralists in arid environments, in certain areas, particularly difficult. This may be exacerbated by competition over access to pasture and water, livestock raiding and the widespread use of sophisticated firearms. This is, in part, exacerbating clashes between herders and farmers in the Sahel, fighting in the Oromia and Ogaden regions of Ethiopia and violent conflicts in northern Nigeria, Sudan and Kenya. Because security concerns are higher with the coming of the rains than during the drought, pastoral conflicts point at the strong role institutional governance can play in facilitating resource access and resource sharing to prevent and mitigate these factors of conflict.

Outside arid regions, the Albertine Rift in the DRC, one of the most biodiverse, ecologically unique regions of Africa, is also in a constant struggle to end an on-going civil war. Its abundance in mineral resources has sadly contributed to this region being "the center of some of the world's most devastating conflicts in recent history. This turbulent context can [thus] be both the seed of conflict and the foundation for peace-building and ensuing development" (Adano *et al.*, 2012, p3.). Thus, Africa, with its history of ethnic, natural resource and interstate conflicts, is seen as being particularly vulnerable to the new climate-induced security threat. "Despite being the continent least responsible for the emission of global greenhouse gases, one of the principal contributors to climate change, it will suffer the consequences of a changing climate most severely. Climate change is today being recast as a security threat, rather than being just an environmental issue" (Adano *et al.*, 2012, p.1).

1.3.8.4.2 The impact of violent conflicts and the reconstruction of society

The effects of conflict are perverse and pervasive. The most direct, of course, are the loss of human life, the destruction of wildlife from poaching or land mines, over-exploitation and degradation of natural resources, and increases in land and water pollution. Daskin *et al.* (2018), for example, showed that the frequency of conflicts can predict the severity of population declines for large mammals in protected areas in Africa. Habitats are destroyed and whole ecosystems degraded and fragmented. This has long-term implications for security, be it food security, health security, water security, or social security. In addition, a whole illegal economy tends to take root around the richest natural resources areas (with valuable, easy to move extractives), perpetuating the loot-seeking dimensions of the conflict. Buchanan-Smith *et al.* (2013) draw attention to the fact that the informal legal fields that develop during war will usually be stronger than old or new laws, which, adding to the problem of displaced populations and returnees, can complicate post-conflict reconstruction and peace-building.

Land issues, as mentioned earlier, are fundamental to reconciliation and economic rehabilitation in countries emerging from protracted conflicts: governance of the tenure regime, access to land, security of tenure and distribution of land holdings provide the building blocks for sustainable security. However, in post-conflict situations, they are also more fluid and open than perhaps at any other time and, thus, the post-conflict period poses many operational tensions (Clover, 2007 in Buchanan-Smith *et al.*, 2013). Wily (2009) makes the point that, if peace is to last, the focus must be on reforming property relations where these were at the heart of the conflict rather than focusing on post-conflict restorative justice and on restitution of property to the displaced. Valuable lessons can, indeed, be learned from what has worked or failed in peace processes around the world. A review of seven peace agreements across the African continent since the early 1990s demonstrates how inadequately issues of land and natural resources are dealt with in peace agreements (Buchanan-Smith *et al.*, 2013). However, progressive initiatives are being put forward, as in Sudan where the Darfur Land Commission undertook a major land-use mapping exercise in order to produce the "Darfur States Land-Use Mapping Database" submitted to the Darfur Regional Authority for approval and updated every five years. In addition, the Darfur Land Commission has undertaken a major exercise in documenting customary land management mechanisms, while parties to land disputes were encouraged to exhaust traditional methods of dispute settlement, including arbitration, before going to court. Therefore a system of legal plurality was built into the management of land in Darfur (Buchanan-Smith *et al.*, 2013).

1.3.8.5 Trade issues in the governance of biodiversity and ecosystem services

A good deal of the literature on biodiversity and ecosystem services related trade focuses on issues related to the illegal trade of wildlife and plant species protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (also see Chapter 4). This has been largely documented in relation to the illegal trade of ivory, rosewood or ebony, for example.

Payments for Ecosystem Services are also a growing theme in science and policy. Reducing Emissions from Deforestation and Forest Degradation (REDD+), for instance, a program to reduce emissions from deforestation and degradation of forests, is investing a few hundred million US dollars in a country such as DR Congo. One of the ultimate objectives of Payments for Ecosystem Services schemes, including carbon trading, is to develop an international market for environmental services in which some conservation and development benefits would be traded against each other for overall mitigation of greenhouse gas emissions and/or environmental degradation. However, some of the hypotheses regarding (growing) carbon markets have not yet materialized, while payments for ecosystem services remain small globally, with global payments for ecosystem services income estimated at just over $1.9 billion per year from 2005 to 2010, and $2.5 billion in 2011 (FAO, 2014a). In addition, Africa, with only 0.9% of global payments in 2011 (and 0.2% in the five previous years), benefits the least from payments for ecosystem services. Other regions do on orders of magnitude better, with China and the United States accounting for the majority of global income (Diaw, 2014).

Strategically, a number of critical questions must be considered in the assessment of BES trade issues for Africa. Currently, only 10–13% of Africa's trade is done internally. By contrast, the proportion in Europe and Asia is close to 60%. This means that African trade is largely extroverted, including BES-related trade. The signing in early 2015 of the Tripartite Free Trade Agreement by 16 of 26 prospective members is the boldest African initiative ever taken to change the situation. The Tripartite Free Trade Agreement holds the prospect of an internal market of 26 countries and 625 million people with a combined GDP of over $1 trillion. This is staggering for Africa, but many issues will need to be resolved before it becomes a reality. For instance, Africa's most advanced and most diversified economies have significant infrastructure, manufacturing and services. Services accounted for 70% of the growth of Morocco, Tunisia, South Africa and Egypt in 2000–2010. These economies also tend, however, to have higher unit-labour and input costs than other African countries, which could require adjustments from some governments[2]. The Tripartite Free Trade Agreement is meant to be a first step in breaking the

[2] *Weighing the options.*Financial Mail, August 6 – August 12, 2015, p. 32. On the Tripartite Free Trade Agreement, see also analyses from the Tahir Institute for Middle East Policy, http://timep.org/commentary/tripartite-free-trade-area/ and Quartz Africa, http://qz.com/424557/the-tripartite-free-trade-area-agreement-in-africa-is-bound-to-disappoint/

continent's notoriously disadvantageous terms of trade. It would also serve as a template for the Continental Free Trade Area, which the summit of African Union leaders endorsed in January 2012 as a 2017 target. There are clearly significant hurdles ahead, including infrastructure, rules of market integration and political stability; but the potential is clear. In that perspective, it will be important to identify and map the specific nature and importance of the BES-related goods traded both internally and as foreign exports, and their importance in global value chains. This will help support calculated shifts in reinforcing inter-African trade and trade networks for both primary and processed BES-related food and consumer goods. A characteristic of most African countries is the dominance of resource/raw material exports with little processing and downstream value addition. Cross-country differences in that regard (for instance, between North & South African industrial infrastructures and that of most other countries) have important free trade implications that, in addition to infrastructural and regulatory issues, will affect the pace of integration in the Tripartite and Continental Free Trade Areas.

A recent paper published in *Current Biology* (Laurance *et al.*, 2015) raises new issues. The authors claim to have assessed the potential environmental impacts and agricultural potential of 33 planned or existing development corridors totalling over 53,000 km in length across much of the African continent. The corridors have been proposed, or are being created, to increase agricultural production as well as inter-African trade through large-scale expansion of infrastructure such as roads, railroads, pipelines, and port facilities. According to Laurance *et al.* (2015), the corridors would bisect over 400 existing protected areas and could degrade a further ∼1,800 by promoting habitat disruption near or inside the reserves. The authors conclude that many of the development corridors will promote irreversible environmental changes and that some should be "cancelled altogether" and others linked "to rigorous mitigation and protection measures". However, Africa's need to develop its infrastructure and internal market in ways that are balanced and smart and that protects its economic and environmental future, remains a major policy consideration.

Approaching from a different angle, Youm *et al.* (2011) looks at the role of trade in introducing invasive pests and disease vectors that can cause environmental damage and economic losses and pose a serious risk to biodiversity. This is a two-way problem, with non-tariff barriers being imposed on African countries under the perception that they are a source of invasive pests to other countries via trade. Fruit flies, for instance, are among the pests that cause major trade losses and agriculture-related income losses to African countries. The paper considers the phytosanitary measures African countries have, therefore, to take to reduce losses in economic and trade opportunities. On the other hand, African countries lack the full capacity to reduce trade-related pest invasions from other countries and the impact of such invasions on African economies and the environment. Other issues to address relate to food quality and costs, international standards in product quality and labelling, inflated costs of transport, the price of goods and products, and hidden trade protectionism from northern economies through the imposition of standards higher than international standards. The question of the African internal market is tightly connected to issues such as this. African bio-products in an integrated African market should enjoy a better competitive advantage, but this will require significant effort in this area.

1.3.9 Sustainable use of ecosystems and green-blue economy

The Millennium Ecosystem Assessment (MA, 2005) reported, as mentioned earlier, that over 60% of the world's ecosystem goods and services were degraded or unsustainably utilised. Sustainable economies are comprised of economic capital, social capital and environmental capital. However, if increases in economic and social capital cannot keep pace with the dwindling environmental capital, then economies will decline (UNEP, 2012b). Climate change and the demands of a growing population only serve to make more crucial the role of ecosystems and environmental capital in sustaining economic and social well-being (UNEP, 2012b). According to a recent review on how SDGs may "play out for Africa" (Nhamo, 2017) states that "issues that include gender and women, education, desire to prioritise Africa and technology emerge strongly". Nhamo (2017) concludes that "if the SDGs are to be a vehicle for poverty eradication in Africa, the continent needs to do more by itself, including domestic mobilization of financial resources".

As mentioned, Africa is endowed with rich and diverse renewable and non-renewable natural resources, yet its people remain among the poorest in the world (World Bank, 2012b). Currently, national accounting and global economic models do not account for all essential contributions of nature to people, especially in the long-term, leading to the overuse or misuse of natural resources (UNEP, 2010). Without full valuation of less-tangible benefits from ecosystems, use is likely to remain unsustainable and degradation inevitable, leading to the potential collapse of important ecosystem functions and services. Care of ecosystems and the benefits they provide can serve as the underpinning foundation on which a sustainable economic model can be developed (UNEP, 2010). One such desired model is the Green Economy, a concept that balances natural resource values with other values, and takes into account the loss in value of ecosystem services due to environmental impacts (UNEP, 2010). The decline in the ecological health and economic productivity of the world's oceans and terrestrial environments can be reversed by shifting to a greener, more sustainable economic paradigm in which human well-being and social equity are improved, while environmental risks and ecological scarcities are reduced (UNEP, 2012b).

The term Blue Economy appears in a book by Pauli (2010) and was developed as a concept to complement that of the green economy, recognising that seas and oceans are a key part of the needed transformations towards a low-carbon economy (UNEP, 2012b). The key aim for a transition to a green and blue economy is to enable economic growth and investment (characterised by reduced carbon emissions and pollution and improved energy efficiency) while increasing environmental quality (through reduced loss of biodiversity and ecosystem services) and social inclusiveness (UNEP, 2011). The concept of a green and blue economy does not replace sustainable development; since achieving sustainability depends on achieving such economic balance (UNEP, 2011). Such an approach requires including natural capital and biodiversity as the competitive edge for Africa, transforming and adding value to the green wealth in regional accounting and having inclusive investments, scalable and viable over a long time.

The Government of Botswana co-hosted the Summit for Sustainability in Africa in 2012, which resulted in the Gaborone Declaration (GDSA, 2012), a concrete set of proposals related to recognising the role of natural capital in development. In 2013, the 10 signatory countries reconvened to take stock and operationalise how to bring natural capital from the periphery to the centre of all economic decision-making.

Following this declaration, the core Wealth Accounting for Valuation of Ecosystem Services (WAVES) countries have begun implementing Natural Capital Accounting. Apart from Botswana, Madagascar and Rwanda are making progress in this program with the World Bank. The WAVES partnership include the UNEP, the UNDP, and the UN Statistical Commission (http://unstats.un.org/unsd/statcom/commission.htm); the countries of Botswana, Colombia, Costa Rica, Madagascar and the Philippines (implementing programs); as well as financial or other support from Australia, Canada, France, Japan, Norway, the United Kingdom, and several NGOs (see more details in Chapter 6).

Africa's 2050 integrated marine strategy (AU, 2013) recognised that the African Marine Domain (AMD) has vast potential for wealth creation through the Blue Economy. The Strategy provides a broad framework for the protection and sustainable exploitation of the AMD and highlights that Member States have significant responsibilities for generating the desirable political will for implementing the strategy. This was later consolidated by the African Union 2063 Agenda, which marked the member countries' political will and strategic decision to make Africa's green and blue/ocean economy a major contributor of Africa's growth and transformation (AU, 2015b).

The transition towards a green economy raises several policy questions. Specific enabling conditions, such as national regulations, policies, subsidies and incentives, as well as international market and legal infrastructure, trade and technical assistance, sustainable development strategies, poverty eradication and skills development, are required (UNEP, 2011; Nhamo, 2013). At the heart of the green economy is the need to address the negative impacts associated with climate change (Nhamo, 2013), energy insecurity and ecological scarcity (UNEP, 2011). A green economy can meet this challenge by offering a development path that reduces carbon dependency, promotes resource and energy efficiency, lessens environmental degradation, improved equity and job creation, and adaptation to rather than mitigation of climate change (UNEP, 2011, 2012a; Nhamo, 2013). A green economy recognises that the goal of sustainable development is improving the quality of human life within the constraints of the environment (UNEP, 2011).

Actions towards harnessing the Green-Blue Economy for Africa's Development in order to exploit the abundant opportunities offered by lands, waters, seas and oceans to accelerate structural transformation in Africa also requires reconsidering several paradigms on sustainable use and poverty reduction. The paradigm shift is already being made by the governments who want to converge with the rest of the world, which means technology acquisition, innovation, investment, getting the finance and using internal means as much as possible to do so. Africa is in a unique position to undertake a more balanced approach here. Thus, instead of keeping the continent at the margin of poverty, with incredibly high international trade deficits and quasi-subsistence, low productivity, lowly competitive and weakly diversified economies, Africa can invest in structural transformation and industrialisation and invest in approaches that support green and blue economies.

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Executive summary

Africa's natural assets and associated contributions to people are underutilised in some areas, but are generally in decline due to a range of natural and human activities *(well established)*. Use and distribution of water resources are uneven among both water-scarce and water-rich regions, countries and communities, and remains, in certain areas, a source of conflict. Africa has abundant and diversified energy sources, including oil and gas and clean energy; but access remains uneven. Renewable energies could provide economically and environmentally attractive alternatives for many countries, while realisation of hydropower potential has remained limited. Despite the presence of a significant portion of the world's arable uncultivated lands, both food production and access experience patterns of constraint in certain areas. Furthermore, little value is added to agriculture, forest, agroforest, livestock and fishery products through industrialisation and processing {2.4.1, 2.4.2}.

Africa's waters are known for the abundance of their fishery resources, with the six Large Marine Ecosystems (LMEs) ranking within the first four most productive LMEs in the world *(inconclusive)*. The fisheries of Africa provide a source of livelihood for 8 million active fishers and their families. If all catches were landed in Africa, African fisheries could contribute a landed value of $20 billion to national economies, with an additional 3.6 billion injected by the small-scale fishing sectors across the value chain. Despite regional differences, current trends in fisheries catch data from LMEs in Africa reaffirm a need for equitable and sustainable use. Overall catches increased from 2.1 million tons in 1950 to 16.7 million tons in 1988 and then decreased to 12.4 million tons in 2010. The artisanal sector, whose landed value reached $4 billion in 2010, is in decline since 2004 along with the industrial sector's catch, despite an increasing fishing effort {1.3.4.1.2, 1.3.4.1.3, 2.2.1}.

Non-Timber Forest Products (NTFPs) contribute significantly to maintain livelihoods of rural communities in Africa *(well-established)*. There is a growing evidence that NTFPs are essential income source in the total household economy in African rural communities in Africa. For example, wild and plants fruit trees on common land make up to 15%, 10% and 27 of total income (subsistence and cash income) in Malawi, DRC, and Ethiopia respectively. Due to growing demand for conversion of land for cultivation purposes, growing populations in certain areas, the availability of NTFPs is threatened {2.2.1.2}.

Woodfuel plays an important role in energy provision in Africa (in particular sub-Saharan Africa) and serves as a critical resource for physical and socio-economic development in both rural and urban communities, a trend that is likely to continue *(well-established)*. Woodfuels account for >80% of primary energy supply in sub-Saharan Africa, where >90% of the population rely on firewood and charcoal for energy, especially for cooking. The demand for charcoal is growing and is expected to increase further, with likely negative effects on health, socio-economic activities and environmental health under business-as-usual scenarios. Despite woodfuel values and increase in demand, the topic tends to be under-represented in policy, with emphasis instead on the need to gaining access to 'modern energy' sources such as electricity and kerosene. Africa sees a clear need to promote and guarantee renewable energy security, availability, and reliability for human comfort {1.3.4, 2.2.1.2}.

Africa has a significant amount of undocumented indigenous local knowledge that would enhance our understanding of biodiversity and ecosystem services status and trends *(inconclusive)*. Indigenous local knowledge of the status and trends of biodiversity may be particularly critical in Africa, due to the relative dearth of scientific biodiversity studies relative to other regions (Chapter 3).

Indigenous and local knowledge is critical to the management and sustainable use of biodiversity and ecosystem services in Africa because of the strong but poorly understood links between biodiversity, ecosystem services, spirituality, culture, and identity. Africa's high cultural diversity with a multitude of unique ethnicities and social groups shows specificity with regards to resource use and management of selected material and non-material nature's contributions. This diversity also results in different perception of nature and interaction with natural ecosystems, thus building unique indigenous and local knowledge for the various countries and localities in the continent over millions of years of interaction between indigenous and local people and nature {2.2.3.3, 4.4.7}.

2.1. Introduction

The Millennium Ecosystem Assessment (MA) contextualized, in 2003, the linkages between nature and human well-being with the concept of Ecosystem Services (Beaumont *et al.*, 2007; Balvanera *et al.*, 2006; Akachuku, 2008; Nelson *et al.*, 2009). More recently, in 2015, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) conceptualised nature's benefits (ecosystem goods and services) to people, their contribution to good quality of life, including the drivers of change and the impacts they have on human well-being as the nature's contributions to people, arranged into three main categories (Table 2.1; Figure 2.1): material contributions, non-material contributions and regulating contributions (Díaz *et al.*, 2015). Since the adoption of the 2011–2020 Strategic Plan for Biodiversity, the focus has been as to how to mainstream the concept of natural assets and ecosystem services into policies and decision-making processes. As indicated in Chapter 1, integrating ecosystem services into policy is critical for the African continent, as ecosystem services have not yet been regarded as a crucial element of the human systems.

Chapter 2 reflects on the IPBES conceptual framework boxes "Nature's contributions to people" and "Good quality of life", as well as the valuation of NCP and ecosystem services values when available. The chapter reflects Goal D of the Strategic Plan for Biodiversity, which is to enhance the benefits to all from biodiversity and ecosystem services. It further addresses issues related to the Aichi Biodiversity Targets, the Sustainable Development Goals (SDGs) and the Intergovernmental Platform for Climate Change (IPCC). It assesses the values and status of nature's contributions to people, including the interrelationship between biodiversity; ecosystem functions and society; the geographical differences between production and use of ecosystem services; and trends and future dynamics of ecosystem goods and services.

Overall, NCPs are particularly important in Africa since a large proportion of the population live in rural areas, and rely quasi-exclusively on material ecosystem services for their livelihoods and, to a significant extent, for their health. Nevertheless, quantity and quality of NCPs tend to decrease due to the overuse of resources, degradation of natural habitats and biodiversity, the increase of all kinds of pollution alongside with the current and future changes incurred by climate change (Chapters 1, 3, & 4). Valuation of ecosystem services is recent in Africa and limited to the provisioning services for food (fish), raw material (wood), medicinal uses (plants, etc.) and regulating ones (water). In this regard, limited monetary values have been produced for a limited number of services. Valuation of NCP has proven to be a useful method to define baselines as well as indicating changes in food, energy, livelihood and health security; and their linkages to biodiversity and ecosystem functions and services that are also critical to social relationships, spirituality and cultural identity.

The objective of this chapter is to present an assessment, at the scale of Africa, of two components of the IPBES conceptual framework: NCP in terms of goods and services and to a good quality of life. The Assessment focuses on NCP in the Africa continent in terms of their geographical differences, their values, status, trends and future dynamics, as well as their impact on human well-being. The approach is based on geographical setting according to the five subregions of Africa (North, South, West, East, and Central), and different units of analysis: tropical and subtropical dry and humid forests; Mediterranean forests, woodlands and shrubs; tundra and high mountain habitats; tropical and subtropical savannas and grasslands; dry lands and desserts; wetlands (peat lands, mires and bogs); urban and semi urban areas; cultivated areas; freshwater (brackish and marine); Inland surface waters and freshwater bodies; shelf ecosystems (neritic and intertidal/littoral zone); open ocean pelagic systems as well as deep sea and coastal areas. The review focuses on NCP in terms of their production and contribution, their use and non-use values by means of different valuation methodologies (biophysical, social, cultural, and economic); their impact on human well-being in relation to basic material for good life, health, livelihood security and on freedom. It further highlights status and trends of some of the continent`s representative NCP. Approaches pertaining to future dynamics of NCP involve reviewing some of the key projects that are undertaken in the region related to reforestation/afforestation; avoided deforestation; sustainable forest management; agroforestry and energy efficiency, amongst others.

The chapter is structured into 4 sections. In the first section, values and valuation of NCP for material and regulating contributions are presented. In the second section, the geographical differences in production and contribution of ES are reported, while in the following section, the status, trend and future dynamics of NCP are described. In the fourth section, the impacts of NCP changes on human well-being are introduced. The conclusion recalls the main elements of the Assessment review.

A) MATERIAL–COMMERCIAL VS LOCAL PROCESSING

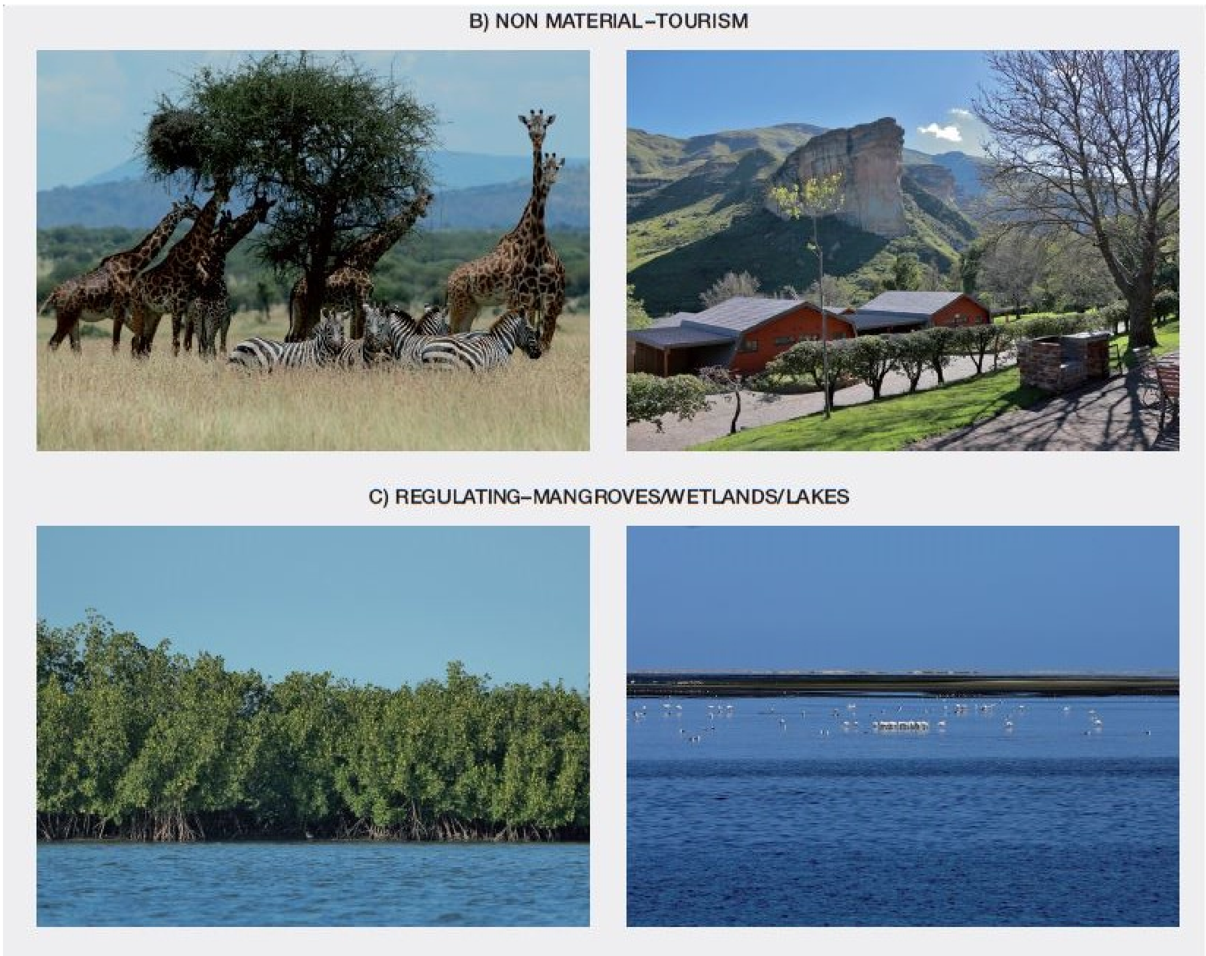

Figure 2.1: Examples of nature's contributions to people: (a) Nature's material contributions: More than 400 million Africans rely on fish as a source of animal protein, and several hundred million people depend on fish as their main source of income. Better processing and marketing technologies can slash post-harvest losses by more than half, generating $350 million and ensuring that 350,000 tons of additional fish will reach the poor. The continent is projected to need an additional 1.6 million tons of fish a year by 2030 just to maintain current consumption. This demand will increase by a further 2.6 million tons a year by 2050. (b) Nature's non-material contributions: Both land- and seascapes provide important areas for recreation, relaxation, healing, nature-based tourism and aesthetic enjoyment, religious and spiritual fulfilment, cognitive development, as well as the promotion of social cohesion and a sense of identity. Tourism is well developed and an important source of income in the northern, southern, and eastern parts of Africa, as well as the oceanic Islands. Many sites in Africa have been classified as protected or heritage sites for their non-material contributions. Many forest locations have been earmarked as sacred sites. In Tanzania, for example, more than 600 sacred groves exist in the North Pare Mountains. (c) Regulating contributions: These contributions from nature are increasingly being appreciated and valued higher in national accounting systems. Highly valued services are mainly linked to agricultural production, including climate, air and water regulation, disease and pest control, and pollination. Other services include nesting, feeding and mating sites for birds and mammals, such as the Key Biodiversity Areas. Key Biodiversity Areas are more and more integrated into national protected systems (Figure SPM 7).

Table 2.1: The 18 categories of nature's contributions to people used in IPBES assessments with regional case studies of relevant key references that refer to these categories.

Regulating contributions–Functional and structural aspects of organisms and ecosystems that modify environmental conditions experienced by people, and/or sustain and/or regulate the generation of material and non-material benefits. In many cases, these NCP are not experienced directly, for example, many people directly enjoy useful, beautiful or otherwise meaningful plants, soil organisms that are essential for the supply of nutrients that underpin growth and long-term survival of such plant species. Sometimes regulating contributions impact people's quality of life directly; for example, avalanches have a direct negative effect on people who live in avalanche-prone areas, and therefore their prevention or favouring by different kinds of vegetation directly affect people's quality of life.

Categories of NCP	A brief explanation and some examples	Values type	Study region	Source
Habitat creation and maintenanc e	The formation and continued production, by ecosystems or organisms within them, of ecological conditions necessary or favourable for organisms important to humans (e.g., nesting, feeding, and mating sites for birds and mammals, resting and overwintering areas for migratory mammals, birds, and butterflies, nurseries for juvenile stages of fish)	Instrumental	East Africa and adjacent islands and Southern Africa	Reynolds *et al.*, 2011; Wangai, *et al.*, 2017
Pollination and dispersal of seeds and other propagules	Facilitation by animals of movement of pollen among flowers, and dispersal of seeds, larvae or spores of organisms important to humans	Instrumental	Africa	Gemmill-Herren, 2014
Regulation of air quality	Regulation (by impediment or facilitation) by ecosystems, of CO_2/O_2 balance, O_3 for Ultraviolet-B absorption, levels of sulphur oxide, nitrogen oxides, volatile organic compounds, particulates, and aerosols	Instrumental	Africa	Chianu *et al.*, 2011
	Filtration, fixation, degradation or storage of pollutants that directly affect human health or infrastructure			
Regulation of climate: Climate regulation by ecosystems (including regulation of global warming)	Positive or negative effects on emissions of greenhouse gases (e.g., biological carbon storage and sequestration; methane emissions from wetlands)	Instrumental	Mauritiu s	Munang *et al.*, 2013; Mbow *et al.*, 2014
	Positive or negative effects on biophysical feedbacks from vegetation cover to atmosphere, such as those involving albedo, surface roughness, long-wave radiation, evapotranspiration (including moisture-recycling)			
	Direct and indirect processes involving biogenic volatile organic compounds			
	Regulation of aerosols and aerosol precursors			

Regulation of ocean acidification	Regulating, by photosynthetic organisms (on land or in water), of atmospheric CO_2 concentrations and so seawater pH, which affects associated calcification processes by many marine organisms important to humans (such as corals)	Instrumental	Mauritius, Africa	Lloyd *et al.*, 2012
Regulation of freshwater quantity, flow, and timing	Regulation by ecosystems, of the quantity, location, and timing of the flow of surface and groundwater used for drinking, irrigation, transport, hydropower	Instrumental	Africa	Lévêque, 1997
	Regulation of flow to water-dependent natural habitats that in turn positively or negatively affect people downstream, including via flooding (wetlands including ponds, rivers, lakes, swamps)			
	Modifying groundwater levels, which can ameliorate dryland salinization in unirrigated landscapes			
Regulation of freshwater and coastal water quality	Regulation– through filtration of particles, pathogens, excess nutrients, and other chemicals–by ecosystems or particular organisms, of the quality of water used directly (e.g., drinking) or indirectly (e.g., aquatic foods, irrigated food and fibre crops, freshwater and coastal habitats of heritage value)	Instrumental	Kenya, Comoros Island, and Tanzania	Comte *et al.*, 2016
	Role of mangroves and seagrasses in this regulation process show in West Africa			
Formation, protection, and decontamination of soils and sediments	Sediment retention and erosion control, soil formation and maintenance of soil structure and processes (e.g., such as decomposition and nutrient cycling) that underlie the continued fertility of soils important to humans. Filtration, fixation, degradation or storage of chemical and biological pollutants (pathogens, toxics, excess nutrients) in soils and sediments that are important to humans	Instrumental	Africa	Symeonakis *et al.*, 2010
Regulation of hazards and extreme events	Amelioration, by ecosystems, of the impacts on humans or their infrastructure caused by e.g., floods, wind, storms, hurricanes, seawater intrusion, tidal waves, heat waves, tsunamis, high noise levels	Instrumental	Africa	Tall *et al.*, 2013
	Reduction, by ecosystems of hazards like landslides, avalanches			
Regulation of organisms detrimental to humans	Regulation, by ecosystems or organisms, of pests, pathogens, predators, competitors, etc. that affect humans, plants, and animals	Instrumental and intrinsic	Africa	Grzywacz *et al.*, 2014
	Regulation by predators or parasites of the population size of non-harmful important			

	animals (e.g., large herbivore populations by wolves or lions)			
	Regulation (by impediment or facilitation) of the abundance or distribution of potentially harmful organisms (e.g., venomous, toxic, allergenic, predators, parasites, competitors, disease vectors, and reservoirs) over the landscape or seascape			
	Removal of animal carcasses and human corpses by scavengers (e.g., vultures in Zoroastrian and some Tibetan Buddhist traditions)			
	Regulation (by impediment or facilitation) of biological impairment and degradation of infrastructure (e.g., damage by pigeons, bats, termites, strangling figs to buildings)			
Material contributions–Substances, objects or other material elements from nature that sustain people's physical existence and infrastructure. (The basic physical and organisational structures and facilities (e.g., buildings, roads, power supplies) needed for the operation of a society or enterprise). They are typically consumable, for example when organisms are transformed in food, energy, or materials for shelter or for some ornamental purposes.				
Categories of NCP	**A brief explanation and some examples**	**Values type**	**Study region**	**Source**
Energy	Production of biomass-based fuels, such as biofuel crops, animal waste, fuelwood, agricultural residue pellets	Instrumental	Mozambique	Batidzirai *et al.*, 2006; Wicke, *et al.*, 2011
Food and feed	Production of biomass-based fuels, such as biofuel crops, animal waste, fuelwood, agricultural residue pellets	Instrumental	Africa	IRENA, 2017
Materials and assistance	Production of materials derived from organisms in crops or wild ecosystems, for construction, clothing, printing, ornamental purposes (e.g., wood, fibres, waxes, paper, resins, dyes, pearls, shells, coral branches)	Instrumental	Africa	Griffis, 1998
	Direct use of living organisms for decoration (i.e., ornamental plants in parks and households, ornamental fish), company (i.e., pets), transport, and labour			
Medicinal, biochemical and genetic resources	Production of materials derived from organisms (plants, animals, fungi, microbes) used for medicinal and veterinary purposes	Instrumental and relational	Africa	Wollny, 2003
	Production of genes and genetic information used for plant and animal breeding and biotechnology			

Non-material contributions–Nature's contribution to people's subjective or psychological quality of life, individually and collectively. The sources of these intangible contributions can be physically consumed in the process (e.g., animals in recreational or ritual fishing or hunting) or not (individual trees or ecosystems as a source of inspiration).				
Categories of NCP	**A brief explanation and some examples**	**Values type**	**Study region**	**Source**
Learning and inspiration	The provision, by landscapes, seascapes, habitats or organisms, of opportunities for the development of the capabilities that allow humans to prosper through education, acquisition of knowledge and development of skills for well-being, scientific information, and inspiration for art and technological design (e.g., biomimicry)	Relational	Niger, Tanzania	Moussa *et al.*, 2008
Physical and psychological experiences	Provision, by landscapes, seascapes, habitats or organisms, of opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure, tourism and aesthetic enjoyment based on the close contact with nature. For example, hiking, recreational hunting, and fishing, birdwatching, snorkelling, gardening	Relational	Côte d'Ivoire, Cameroon	Feka *et al.*, 2008; Kouassi *et al.*, 2013
Supporting identities	Landscapes, seascapes, habitats or organisms being the basis for religious, spiritual, and social-cohesion experiences	Relational	South Africa, Zimbabwe	Radder *et al.*, 2008
	Provisioning of opportunities by nature for people to develop a sense of place, purpose, belonging, rootedness or connectedness, associated with different entities of the living world (e.g., cultural and heritage landscapes, sounds, scents and sights associated with childhood experiences, iconic animals, trees or flowers)			
	The basis for narratives and myths, rituals and celebrations provided			Byers *et al.*, 2001
	landscapes, seascapes, habitats, species or organisms (e.g., sacred groves, sacred trees, totem animals)			
	Source of satisfaction derived from knowing that a particular landscapes, seascape, habitat or species exist in the present			
For all groups of nature's contributions to people				
Maintenance of options	The capacity of ecosystems, habitats, species or genotypes to **keep human options open** in order to support a later good quality of life. Examples include benefits (including those of future			

	generations) associated with the continued **existence of a wide variety** of species, populations, and genotypes			
	Future benefits (or threats) derived from keeping options open for **yet unknown discoveries and unanticipated uses** of particular organisms or ecosystems that already exist (e.g., new medicines or materials)			
	Future benefits (or threats) that may be anticipated from **on-going biological evolution** (e.g., adaptation to a warmer climate, to emergent diseases, development of resistance to antibiotics and other control agents by pathogens and weeds)			
	Ecosystems in Protected areas, and more particularly in marine protected areas have shown a higher resilience capacity than the ones not protected or well managed. Efficient protection measures contribute to the maintenance of options			

2.2. Values and valuation of nature's contribution to people

IPBES's conceptual framework identified three major inclusive elements of the interaction between human societies and the non-human world. These elements are nature, nature's contributions to people, and a good quality of life. This section focuses on the assessment of values attributed to nature's contributions to people in Africa. The values that are attributed to nature's contributions to people are both instrumental and relational and include material contributions such as the provision of food and feeds, regulating contributions such as climate regulation and pollination, and non-material contributions linked to physical and psychological experiences. Figure 2.2 provides a summary representation of the relative proportion of material, non-material, and regulatory values attributed to nature's contribution to people in different sub regions of Africa from the papers considered for the synthesis of information on values of biodiversity in Africa.

In many parts of the world, including Africa, perceptions of the values of nature and its contributions to a good quality of life differ and often result in conflicting views depending on the cultural or institutional setting. This implies that various environmental decision-making efforts would have different implications in different settings, but in reality, independent values are seldom recognised or explicitly taken into account. It thus becomes important that in this assessment (and others), the diversity of perceived values from nature's contributions to people are clearly understood, and not simply ignored or misrepresented at regional and subregional level.

Accounting for the value of nature's contributions to people is challenging in part because nature's contributions to people are often not traded and in part because there are very few formal valuation studies of nature and its contributions to people on the continent of Africa. The extent and quantity of existing valuation studies in Africa is unfortunately limited in geographical scope and types of ecosystems covered (e.g., Turpie *et al.*, 1999; Naidoo *et al.*, 2005; Bignaut *et al.*, 2008; O'Farrell *et al.*, 2011; Egoh *et al.*, 2012; Failler *et al.*, 2012; Failler, 2016). This chapter summarises findings from major studies and assessments that have been carried out to date.

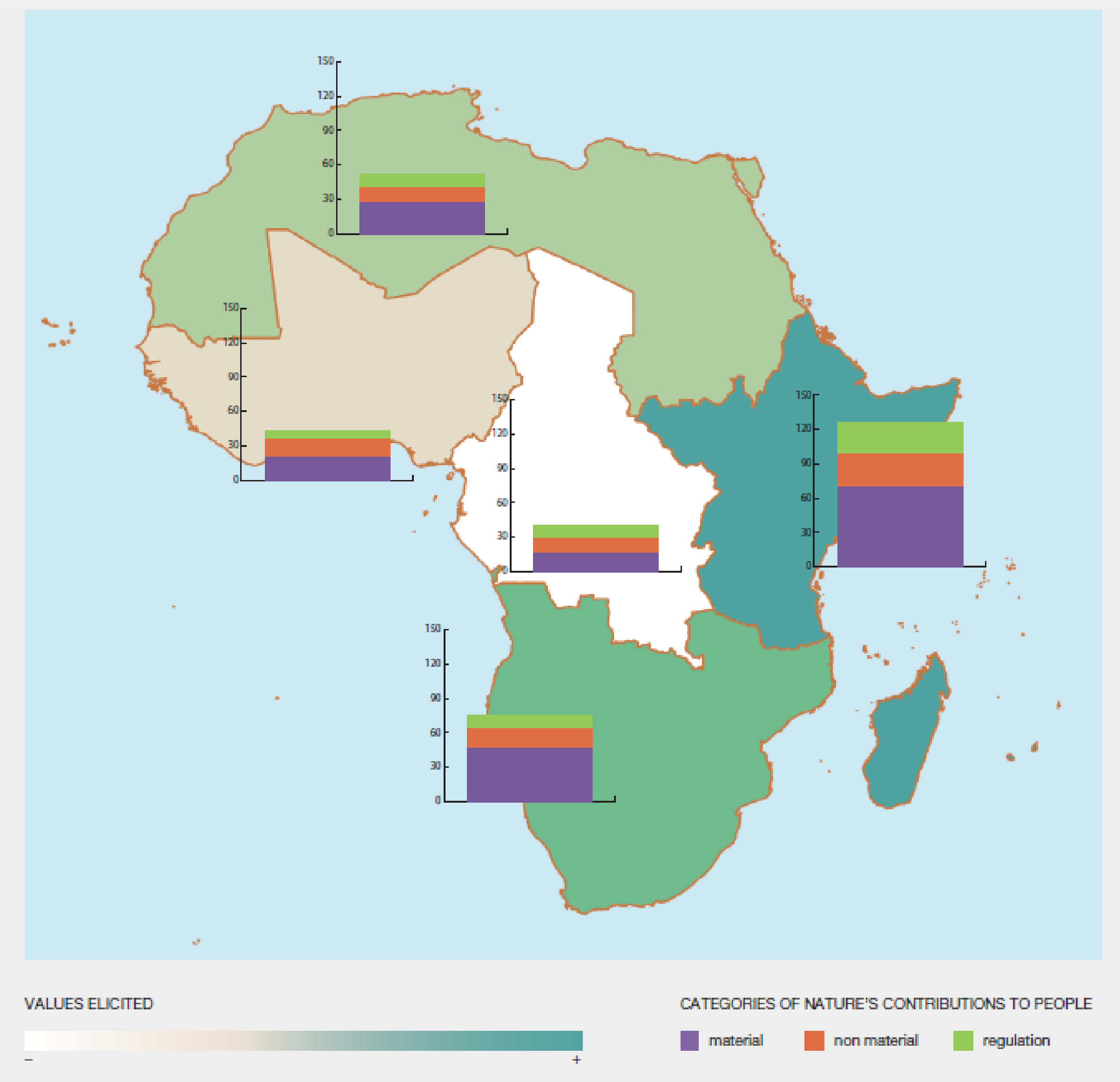

Figure 2.2: Values representation per subregion and targeted nature's contributions to people. Source: see Appendix AfRA 2.1; Available at https://www.ipbes.net/node/add/supporting-material

Along with the spatially explicit ecosystem service research in Africa, pragmatic approaches to ecosystem service valuation have been suggested by Failler *et al.* (2009) and O'Farrell *et al.* (2011), and in their guidelines for the estimation of coastal and marine ecosystem services valuation. O'Farrell *et al.* (2011) estimated grazing values in the Succulent Karoo of South Africa at a range of $19 to $114 million, tourism activities from $2 to $20 million; and services linked to water from $300 to 3120 million. Failler *et al.* (2009) have estimated the total economic value of ecosystem services of marine protected areas in West Africa at $30,000/km^2 (Section 2.4.2.1). More recently, Failler (2016; 2017a & b) has provided, for UNEP, an estimate of African coastal and marine ecosystem services values. These estimates are presented in figure 2.3 alongside with other ecosystem services values.

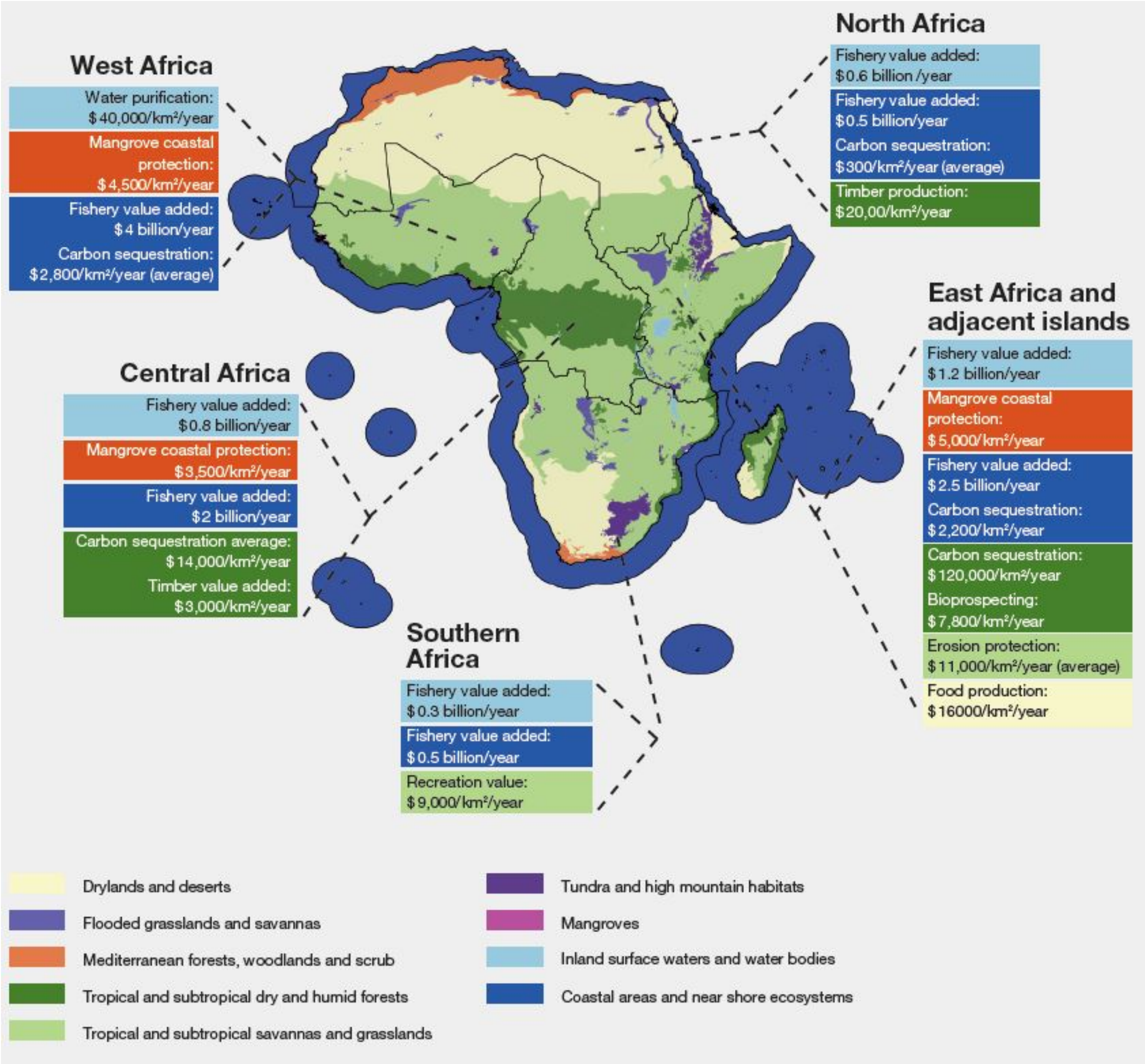

Figure 2.3: Indicative lists of economic values of nature's contributions to people in Africa. Sample values of some ecosystem services in selected ecosystems (freshwater, marine and coastal areas and forests) in Africa. Apart from fishery and blue carbon values, data comes from various sources, with methodological differences, which means comparisons of values between subregions or ecosystems is not currently possible. Source: Map layers: Olson *et al*. (2001); Sample value: (a) **North Africa:** Marine and Coastal fishery value added (FAO FISHSTAT, 2017); Carbon sequestration (Canu *et al*., 2015); Inland waters (de Graaf *et al*., 2014); Forest (Daly, 2016); (b) **West Africa:** Marine and Coastal (Failler, 2016), Wetlands (Failler *et al*. (2012); Inland waters (Acharya *et al*. (2000); (c) **Central Africa:** Marine and Coastal (Failler *et al*., 2017a), Wetlands (Failler *et al*., 2017b), Inland waters (de Graaf *et al*., 2014), Forest (Yaron, 2001); (d) **South Africa**: Marine and Coastal (Mclean *et al*., 2017; Klaus *et al*., 2017), Inland waters (de Graaf *et al*., 2014); Savanna (de Wit *et al*., 2006); (e) **East Africa and adjacent islands:** Marine and Coastal and Wetlands (Mclean *et al*., 2017), Inland waters (de Graaf *et al*., 2014), Forest (Emerton *et al*., 1999), Dryland and Desert (Barrow *et al*., 2007), Savanna (Emerton, 1998).

2.2.1. Material Contributions

Material contributions are the provisioning services that describe the material or energy outputs from ecosystems. The materials considered in this section are food, energy, health, and water. As mentioned in Chapter 1, Africa is rich in biodiversity and draws on diverse forms of plants and fauna to meet its basic human needs (Chapter 3). Its people depend highly on these materials for daily sustenance, construction purposes, fuel, and health and cosmetic purposes, amongst other uses.

2.2.1.1. Food and feeds

Food production serves as an important material contribution of ecosystem services in terms of nature's contributions to people. Many communities in Africa depend on food provided by natural ecosystems such as forests, grasslands, wetland areas and water bodies sustaining fisheries (FAO, 2014) for their food security. The main food items that are sourced come from bushmeat (Olupot *et al.*, 2009; Golden *et al.*, 2011), insects, fresh fruits, nuts, seeds, tubers and green leafy vegetables (Kehlenbeck *et al.*, 2014), edible oils, drinks spices, condiments (Faye *et al.*, 2011), mushrooms, honey, sweeteners, wild tubers, and snails, amongst others.

Hunting bushmeat is a common practice, particularly in Central Africa (Chapters 3 & 4), where it provides high-quality animal protein. Target animals include mostly insects, rodents, birds, reptiles, as well as other primate species (Ajayi *et al.*, 2010; Salami *et al.*, 2011). Larger-bodied species are usually preferred, however, as they generate a greater return on effort invested in hunting (Wilkie *et al.*, 2016; Chapter 3). For example, in the Congo Basin countries, approximately 80% (maximum 98%) of the volume of meat eaten comes from wild animals and contributes between 30% and 80% of the daily fats and protein requirements (Nasi *et al.*, 2011). Bushmeat serves as a cheap and easily accessible resource especially for rural households, who, rely heavily on this resource during the "hungry season" and in situations of stress or emergency (Nlom, 2011; Chapters 3 & 4).

The rate at which urbanisation is growing in Africa, combined with an increasing demand, which is now surpassing supply, there has been a devastating impact on the biodiversity of the region (Kasisi, 2012; Chapters 3 & 4). Figure 2.4 illustrates the rate of increase of bushmeat production in the Congo Basin countries between 1985 and 2005, and table 2.2 further demonstrates the increase in the volume of consumption in the Congo Basin in 2009.

Some regions show positive impacts on biodiversity, however. Fenced and unfenced community conservancies in Namibia and Kenya and private game ranches in South Africa, for example, have been generally (although not always) successful in conservation efforts by mixing wildlife and livestock production (Wilkie *et al.*, 2016). Mixed wildlife–livestock production can increase income for poor rural families when wildlife is sold by hunters as trophies or as meat to high-value tourist lodges and export markets.

Insects comprise another source of protein, minerals, and vitamins. About 250 edible species are listed in Africa, where the dominant 78% represent Lepidoptera (30%), Orthoptera (29%) and Coleoptera (19%), while the other 22 % comprise Isoptera, Homoptera, Hymenoptera, Heteroptera, Diptera, and Odonota. Whether or not insects are eaten depends partly on taste and nutritional value, but also on customs, ethnic preferences and prohibitions. Because most insects are only available seasonally. Preservation by drying is often practiced (van Huis, 2003). Research in Bangui estimated that 29% of the total annual consumption of animal proteins was obtained from caterpillars and larvae, and that during the harvesting period, they accounted for over half of the population's protein consumption (N'Gasse, 2003). Bahuchet (1972) recorded that caterpillar consumption in a forest camp of the Aka Pygmies in the Central African Republic made up 75% of people's protein consumption during the caterpillar season. Many insects also provide commercially value added products, such as honey.

Currently, Egypt is the dominant honey producer, with the highest value of honey in Africa at about €98/hectare (Croitoru, 2007).

Figure 2.4: Bushmeat production in selected countries within the Congo Basin between 1980 and 2005. Source: Ziegler (2009).

Table 2.2: Bushmeat consumption in selected countries within the Congo Basin in 2009. Source: Nlom (2011).

	Cameroon	Central African Republic	Congo	DRC	Equatorial Guinea	Gabon	Total
Total consumption (tons/year)	78,077	12,977	16,325	1,067,873	9,763	11,381	1,196,396
Average harvest (kg/km forest/year)	503	248	77	897	574	50	645
Average consumption (kg/person/year)	21	17	11	41	24	15	35
Bushmeat value ($/year)	195,193	32,443	40,813	2,669,683	24,408	28,453	2,990,990

Wild plants are also an excellent source of food and vitamins and in the absence of regular supply of animal protein and fat (i.e., dairy products and meat, plants are fundamental to nutritional security)

(Maranz *et al.*, 2004; Teklehaimanot, 2004). According to Kronborg *et al.* (2014), the protein contents of the fermented product of *Parkia biglobosa* (soumbala/moutarde in local language), for instance, can surpass that of meat. In West Africa, there are three key species complementing daily rural diets: *Vitellaria paradoxa*, *Parkia biglobosa*, and *Adansonia digitata* (Augusseau *et al.*, 2006; Belem *et al.*, 2007; Heubach *et al.*, 2013), while in Sudan, a wide variety of wild plants are used in everyday meals, such as for salads, drinks (hot and cold), and everyday cooking (Salih *et al.*, 2014).

Plant products are mostly open-access resources (i.e., no financial investment is needed to produce or collect them) (Angelsen *et al.*, 2003). They are available in the dry season when fields are already harvested and are suitable for mid-term storage to provide a buffer during times of seasonal or financial stress (Arnold *et al*., 2001; Schreckenberg *et al.*, 2006). There are many examples of the nutritional values of Non Timber Forest Products (NTFPs) of plant origin across the continent, like Marula (*Sclerocarya birrea*), a source of nutrition and a dietary mainstay in South Africa, Botswana, and Namibia.

Besides bushmeat, insects, and plants, fisheries constitute another key source of food and income derived from nature. Despite regional differences (Belhabib *et al.*, 2016), some major trends can be revealed by analysing fisheries catch data. Data extracted from the Sea Around Us database show that overall catches increased from 2.1 million t in 1950 to 16.7 million t in 1988, and then decreased to 12.4 million t in 2010. The artisanal sector, whose landed value reached $4 billion in 2010, is in decline since 2004, along with the industrial sector's catch, despite an increasing fishing effort. Subsistence sectors, consumption driven fishing activities conducted operated almost exclusively by women, caught 411,000 tons in 2010. Overall, catches by this sector increased, showing high dependence upon fish. With the over-exploitation of fish stocks (Pauly *et al.*, 2015), costs of fishing increased (Teh *et al*., 2013), translating into a shift from subsistence to artisanal fishing (Belhabib *et al.*, 2014).

In sub-Saharan Africa, fish provide over one-fifth of protein intake by local communities. In West African coastal countries such as Ghana and Sierra Leone, the rate of protein uptake from fish is more than half. West African is considered one of the most economically important fishing zones in the world, with a production of 4.5 million tons of fish in 2000 (Belhabib *et al.*, 2014). Southern African countries also constitute exceptional fishing areas and export between 80% and 90% of their marine fish annually (Akpalu, 2013). Other countries such as Egypt, Morocco, Ghana, Kenya, Namibia, Nigeria, Senegal and Uganda, also produce large quantities of fish, which contribute significantly to food security and nutrition in those areas (FAO, 2016). Over 3,300 industrial vessels (20% foreign) and 54,000 artisanal and subsistence pirogues catch over 6.4 million tons of fish per year (Belhabib *et al.*, 2012; Belhabib *et al.*, 2015b), for a landed value of $10.6 billion (Belhabib *et al.*, 2015a). Catches peaked in the late 1990s and have been declining since then, despite or because of an increase in the fishing effort. However, as this region is also targeted by foreign fleets under agreement and illegal fleets, at least 15 of the 18 important coastal demersal stocks and pelagic resources (sardinellas, horse mackerel *Trachurus trachurus*, chub mackerel *Scomber colias*, anchovy, and bonga shad *Ethmalosa fimbriata*) are fully or over-exploited (CCLME, 2016). This raises serious concerns about food security and the sustainability of fishing access agreements with foreign countries (Belhabib *et al.*, 2015a).

The countries of Eastern and Southern Africa and others in the Indian Ocean (ESA-IO) region collectively produce almost 1.9 million metric tons of fish–or 23% of Africa's fish production every year. A special characteristic of the region's fish production is that the greatest proportion of the total catch is derived from diverse inland and fresh water fisheries, rather than marine fisheries (IOC, 2014). Despite this, per capita, fish consumption has stagnated in Africa and only accounts for a tiny share of global fish production, approximately 0.6% and shrinking (CAPMAS, 2014; Soliman *et al.*, 2016). In Figure 2.3, a summary of Africa's material and non-material contribution to people from fisheries is given.

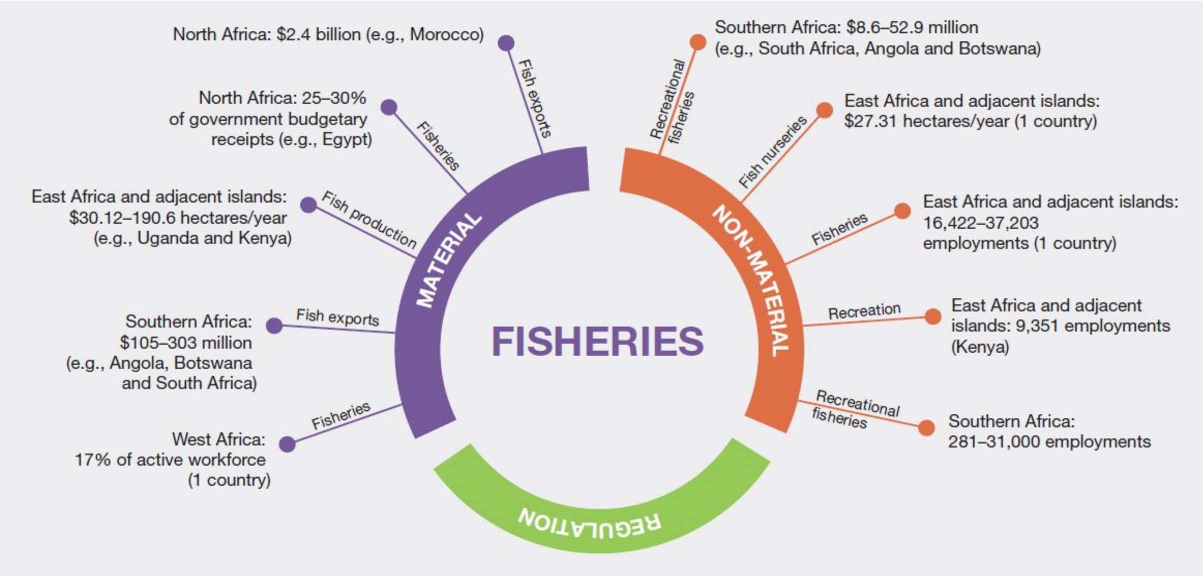

Figure 2.5: Multiple values of fisheries based on their diverse contributions to people. Source: See Appendix AfRA 2.1; Available at https://www.ipbes.net/node/add/supporting-material

Small-scale fisheries are the only source of animal protein to many rural populations and are economically significant in a number of areas in Africa (FAO, 2014). According to FAO (2016), the total fish supply was 11 million tons live weight equivalent or 10.5 kg/year per capita. It was estimated that with a total GDPA of $288.4 billion, this sector contributes 6% of the GDPA for the whole of Africa. The highest contribution is from marine artisanal fishing contributing 1.82% of the total GDPA, whereas inland fishing and marine industrial fishing contribute 1.62% (FAO, 2014).

The successful management of fisheries has to consider the employment of fishers' ILK on the ecology and biology of local fish species. It has been found that the lack of sufficient scientific information on specific fish species was be complemented by the local fishers ILK (Gaspare *et al.*, 2015).

2.2.1.2. Timber and Non-Timber Forest Products (NTFPs) and livelihoods

Forests and woodlands provide valuable ecosystems services by provisioning timber and Non Timber Forest Products (NTFPs), which serve as a diverse source of jobs and livelihoods in Africa. For instance, in Tanzania, the estimated annual revenues generated from timber for domestic use are $10 million in terms of planks, and twice as much when processed into furniture (Schaafsma *et al.*, 2014b). Africa-wide, the annual consumption of wood is projected to grow by over 40% by 2030, and the region as a whole is slated to become a net importer of wood products for fuel and construction. According to Nlom (2011), the formal forestry sector in Congo Basin countries produces more than 10 million tons of timber a year, with production dominated by Gabon (3.96 million tons) and Cameroon (3.16 million tons). A large proportion of this timber is exported–around 50% overall, ranging from 15% in the Central African Republic to over 90% in the Democratic Republic of Congo. The current total annual value of these exports exceeds $2.5 billion, while the estimated market value of domestically-consumed timber and timber products is estimated to total almost $1 billion. The FAO (2013), quantified the total value of forests to rural people in Uganda at about $4.01 billion (Table 2.3).

Table 2.3: The total annual value of forest products to rural people in Uganda. Source: FAO (2013).

Forest product category	Cash value		Non-cash value		The total value of forest products	
	($million)	(%)	($million)	(%)	($million)	(%)
Fuel	406	10.1	1,186	29.5	1,592	39.6
Building materials	346	8.6	655	16.3	1,001	24.9
Forest Foods	241	6.0	510	12.7	752	18.7
Fibre (for ropes, baskets, matting, etc.)	68	1.7	257	6.4	326	8.1
Herbal medicines	44	1.1	145	3.6	189	4.7
Timber	32	0.8	129	3.2	161	4
Total	**1,137**	**28.3**	**2,882**	**71.7**	**4,019**	**100**

Domestic demand for timber in this region is growing, however, which is almost entirely supplied by the largely unregulated, inefficient and unsustainable informal sector, which makes the sector's real contribution to GDP and to local livelihoods challenging to measure (Cerbu, 2016). The region is well known for round wood and timber exports from large forest concessions, traditionally managed by foreign owned companies. Total recorded round-wood harvests for industrial timber are 7.5 million m^3, compared with 1.7 billion m^3 globally (Bromhead, 2012).

In the subregions of East Africa (Kenya, Malawi, Somalia, Sudan, Tanzania, Uganda, Zimbabwe), Teak is particularly valued, mainly for its durability and water resistance, and is used for boat building, exterior construction, veneer, furniture, carving, turnings, and other small wood projects (USDA, 2010). Its leaves are also edible and have medicinal properties (Farinola *et al.*, 2014).

On the African island of Madagascar, endemic species of rosewood is in great demand for veneer, musical instruments (guitar bodies and fingerboards), furniture, cabinetry, inlays, carving, turned objects, and other small specialty wood items. The essential oil can also be extracted from the wood and used for aromatherapy and perfume. The heartwood is traditionally used as medicine to treat malaria, bilharzias, and cysticercose (WHO, 2013).

The southern African region is characterised by the Miombo dry land forests, which cover 2.4 million hectares (twice the area of the Congo Basin rainforests) and span from Mozambique to Angola and including parts of southern Tanzania and southern DRC (Chapter 3). Miombo woodlands provide many services to rural populations, including late dry-season grazing for livestock from foliage, building materials, and a range of non-timber forest products such as honey, ingredients for cosmetics, Amarula (a cream liqueur), etc. (Chapters 1, 3, & 4). According to Kimaro *et al.* (2013), wild tree fruits and edible mushrooms are widely used by local people near Ngumburuni forest reserve in Tanzania.

Non-Timber Forest Products (NTFPs) contribute significantly to the subsistence, daily life, and welfare of people, and could become a major instrument of economic development for some rural communities (Mahaptara *et al.*, 2011; Lambini *et al.*, 2014; Maisharou *et al.*, 2015; Table 2.4). The average share of NTFPs income in total household income in rural Africa is 21.4% (Angelsen *et al.*, 2014; Heubach *et al.*, 2016), with varying figures across countries ranging from 20% in Tanzania (Schaafsma *et al.*, 2014a), to up to 44% in Zambia (Kalaba *et al.*, 2013). Amous (1999) estimated a per capita fuelwood consumption of 0.89 m^3/year and African fuelwood consumption by households is still the highest in the world (Arnold *et al.*, 2003; UN, 2018). Women and children are the main collectors and traders of

NTFPs, and they form a substantial component of women's livelihoods in many rural areas (Arnold *et al*., 2001; Pouliot *et al.*, 2013; Colfer *et al.*, 2015). However, as pointed out by Ambrose-Oji (2011), few countries have explicit laws that govern the harvesting of NTFPs Inventories of all species used and sold would be impossibly costly to undertake, and they recommend creating inventories of only the half dozen most important NTFPs sold in any location.

Table 2.4: The value of NTFPs per country group (Euro/hectare, 2005 prices). Source: Croitoru (2007).

	Firewood	Grazing	Cork	Mushrooms	Honey	Other NTFPs	Total NTFPs
Morocco	17	31	1	1	4	1	54
Algeria	0	36	1	No data	0	0	38
Tunisia	3	81	11	0	2	12	109
Egypt	7	No data	No data	No data	97	No data	104
Average	11	35	2	1	3	1	54

2.2.1.3. Energy

Fuelwood is the dominant source of energy in Africa (World Bank data repository, 2017), with over 90% of energy needs in rural areas supported by fuel wood. Urban areas rely more on charcoal as a source of energy for cooking (Bailis *et al.*, 2005; Figure 2.6). For instance, in Tanzania, direct dependence fuelwood is high; 92% of rural households rely on it for cooking, whereas 50% of the urban population uses charcoal (National Bureau of Statistics Tanzania, 2011). In Central Africa, demand for household energy from rapidly growing urban centres (e.g., Kinshasa; Chapter 3) exerts massive pressure on forests (World Bank, 2013). Nlom (2011), identified fuelwood as the dominant energy source in the Congo Basin (mostly sourced from the natural forest). The annual consumption has been recorded at around 95 million m^3, mainly comprising firewood, with a total value of some $2.8 billion (Table 2.5).

Table 2.5: Value of fuelwood production in Congo Basin countries (2008). Source: Nlom (2011).

	Cameroon	Central African Republic	Congo	DRC	Equatorial Guinea	Gabon	Total
Firewood (m^3)	9,732.50	6,016.50	1,295.10	74,315.30	188.8	534.1	92,082.3
Charcoal (tons)	409.5	185.5	3.6	1,890.00	8.5	19.2	2,516.3
Fuelwood value ($)	304,260	186,060	38,961	2,286,159	5,919	16,599	2,837,958

In East Africa and adjacent islands, 70–85% of urban households rely on charcoal, and between 2000 and 2010 the demand for charcoal grew at 3%/year, while firewood grew at 1%/year (World Agroforestry Centre, 2013; Chapter 3). Charcoal production constitutes an important source of income in rural Africa, but is, in certain areas, at the expense of forest cover (Chapters 1, 3 & 4). Currently wood fuel, i.e., firewood and charcoal accounts for around 10% of global energy supply, but dominates energy provision in many parts of the developing world (OCDE/IEA, 2014).

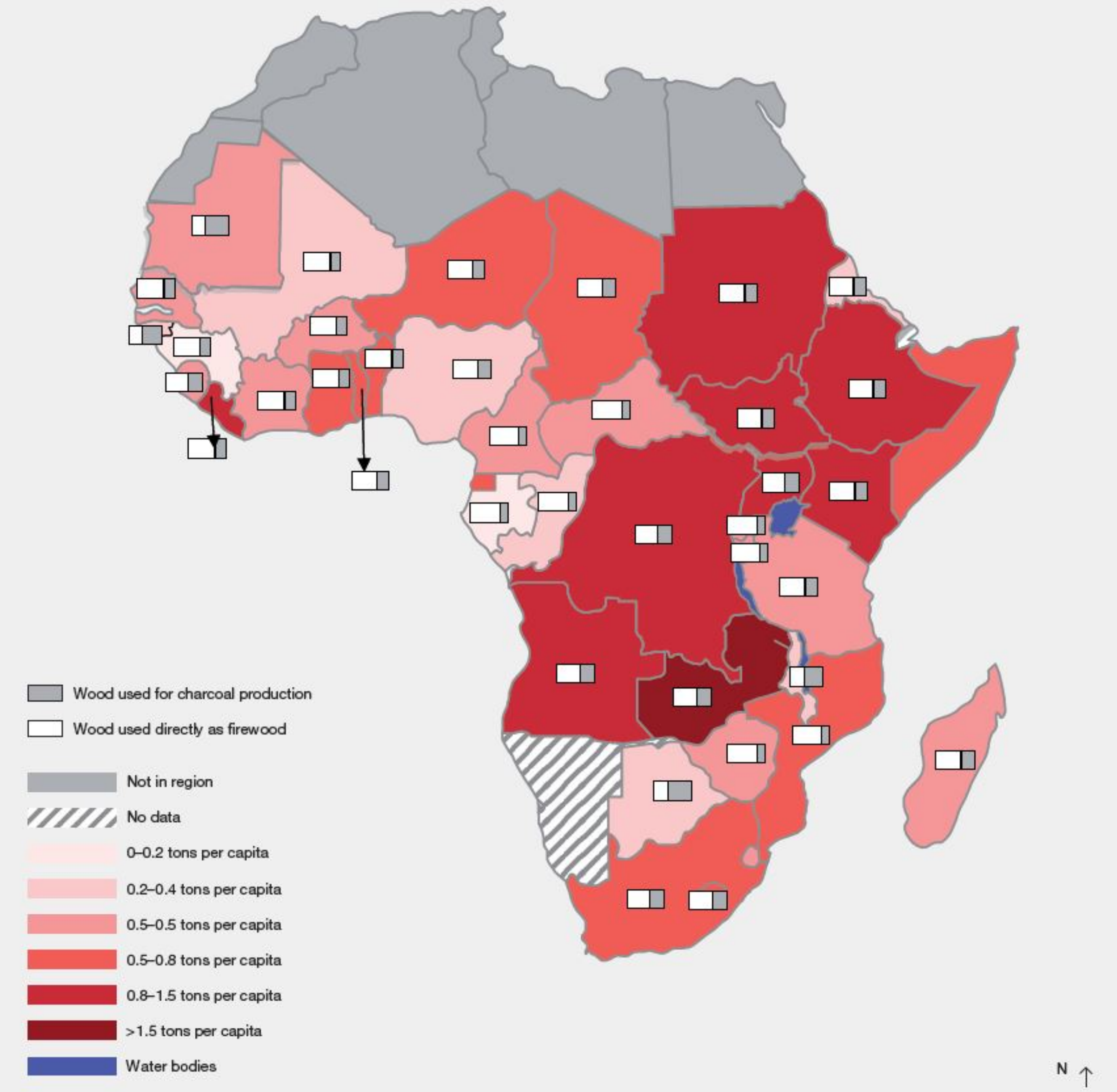

Figure 2.6: "Current per-capita biomass production in sub-Saharan Africa. The colours show total wood fuel consumption, and the pie charts show the fraction of wood that is used for charcoal, based on multiple sources. FAO biomass estimates (including charcoal) were roughly consistent with IEA estimates and were used for all countries except Angola, Kenya, South Africa, Sudan, and Zambia (20% of the region's population). For these countries, FAO biomass estimates would have been too low to meet minimal household energy needs when considered with energy use from fossil fuels and other energy sources reported by IEA. In all of these countries except Kenya, IEA estimates were used; for Kenya, data from a detailed national household fuel consumption study were used" Bailis *et al.* (2005).

In sub-Saharan Africa, wood fuel accounts for > 80% of energy supply and over 90% of the population relies on these sources of energy (Bailis *et al.*, 2005), except in South Africa where levels of electricity supply are relatively high. For instance, it is estimated that four out of five people in the region are reliant on the traditional use of mainly fuelwood, for cooking (Bailis *et al.*, 2005). The expected increase in charcoal demand could significantly negatively impact on tree cover in dry forests and savannas, which supply much of the charcoal sold in the urban areas of sub-Saharan Africa (World Agroforestry Centre, 2013). In most sub-Saharan Africa countries, the wood-based biomass sector contributes significantly to employment, generally providing regular income to a large portion of people. This assumption is based on three studies (in Kenya, Malawi and Tanzania), extrapolated to sub-Saharan Africa to show that the charcoal industry in this region might have been worth more than $8 billion in 2007, with more than 7 million people dependent on the sector for their livelihoods (World Bank, 2012).

Sub-Saharan Africa is rich in energy resources but very poor in energy supply. Hydropower accounts for one-fifth of today's power supply, but less than 10% of the estimated technical potential has been utilised. In Central Africa, only 9% of the population in the DRC has access to electricity. This is an example where huge hydropower potential is surpassed by extreme energy poverty. In East Africa and adjacent islands, mainly in Kenya and Ethiopia, geothermal energy serves as the second-largest source of power supply. Coal production and use gradually extend beyond South Africa, but coal is surpassed by oil as the second-largest fuel in the sub-Saharan energy mix. Nigeria remains the region's largest gas consumer and producer, but significant offshore discoveries in Mozambique and Tanzania are also changing energy supply geography (OECD/IEA, 2014). Figure 2.7 shows patterns of fossil fuel energy consumption at the sub regional level.

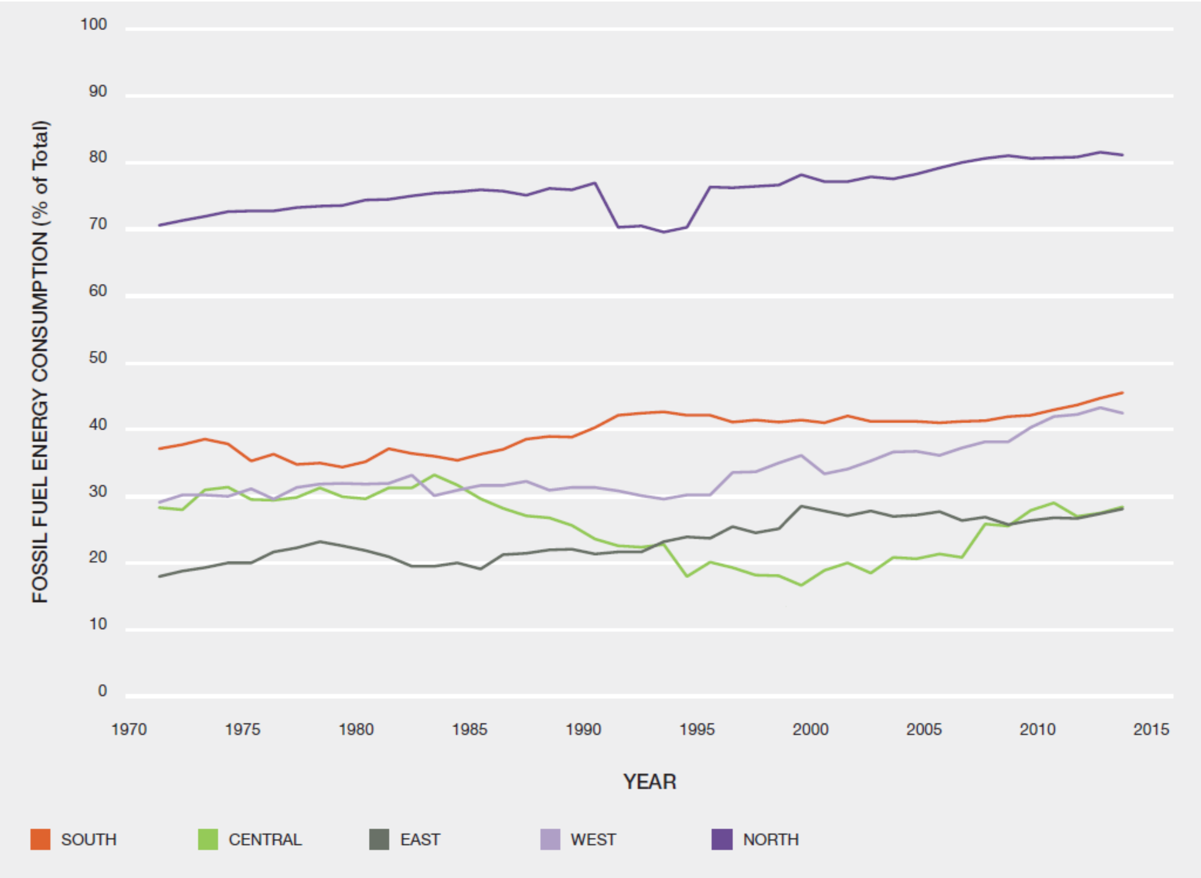

Figure 2.7: Patterns of fossil fuel energy consumption in Africa at the subregional level. Fossil fuel comprises coal, oil, petroleum, and natural gas products. Source: World Bank data repository (2017).

According to IEA, (2009), bioenergy formed almost 50% of the Total Primary Energy Supply (TPES) for the African continent and over 60% of sub-Saharan TPES. Assessments carried out by Stecher *et al*. (2013), indicate that by the year 2020 potentials for bioenergy would rise for; crops (from 0 PJ/year to 13,900 PJ/year), and forestry biomass (from 0PJ/year to 5400 PJ/year). For residues and wastes, however, the potentials will rise from 10 PJ/year to 5,254 PJ/year. In South Africa, bioenergy potentials range from approximately 400 to 550 PJ/ year, where maize and wheat residues currently account for about 104 PJ of the sustainable bioenergy potentials (Batidzirai *et al.*, 2016). National Programmes in biogas production are being implemented in certain countries across the continent (Austin *et al.*, 2012).

Renewable energy markets (sun, water, biomass, and wind) are steadily growing on the continent, despite significant barriers facing implementation of energy projects in Africa, such as fluctuating exchange rates, political and institutional challenges, and falling international commodity prices, (Power Africa, 2016). Africa has significant potential for wind and solar energy; for example, Ethiopia has a capacity of 1,350 GW of energy from wind and annual total solar energy reserve of 2,199 million TWh/annum (Derbew, 2013). Africa's lengthy coastline provides significant potential for wind power production. South Africa, Morocco, Egypt, Ethiopia, and Kenya are currently the five most prominent countries in the wind energy market in Africa (Table 2.6).

Table 2.6: The five biggest wind market in Africa. Source: Tiyou (2016).

s/N	Countries	Operational (MW)	Under construction (MW)
1	South Africa	I, 170	840
2	Morocco	870	50
3	Egypt	750	0
4	Ethiopia	320	0
5	Kenya	14	310
	Total	3,124	1200

Solar power potential in Africa is significant (IRENA, 2016). The price of producing power from solar mini grids is expected to fall by approximately 60% in the next 20 years. According to IRENA (2016), up to 60 million Africans may already have access to renewable electricity.

2.2.1.4. Medicinal, biochemical and genetic resources

According to WHO (2002), up to 80% of the population in Africa rely on traditional medicine to help meet their primary health care needs. Furthermore, numerous plant products are used in traditional African medicine (Moyo *et al.*, 2015; Table 2.7).

Table 2.7: Some medicinal plants used in treatments of some ailments in Africa.

S/N	Plant species	Treatments/ailments	Source
1	*Xylopia aethiopica*	Ante natal care and child birth	Gbadamosi *et al*., (2014)
2	*Garcinia Kola*	Anti-infection treatment, and sexual drive improvement	Gbadamosi *et al*., (2014)
3	*Rauvolfia vomitora*	Purgative	Moyo *et al.*, (2015)
4	*Gmelina arborea*	Carminative in many ailments	El- Mahmood *et al.*, (2010)
5	*Tamarindus indica*	Constipation, obesity, etc.	Mohamed *et al*., (2017)
6	*Prunus africanis*	Benign prostatic hypertrophy, also used in 19 other herbal preparation	Hoare, (2007).
7	*Khaya senegalensis*, and *Combretum Micranthum*	Anti- malaria	Lokossou *et al*., (2012)

8	*Anthcleista nobilis*	Rheumatism	Lokossou *et al.*, (2012)
9	*Newbouldia laevis*	A cough, toothache, and conjunctivitis	Lokossou *et al.*, (2012)

Traditional medicine, in particular, phytotherapy, is widespread throughout the African continent and extends to include practices for treatment of animals ailments and general animals' health care (Halmy, 2016). Both women and men practice folk medicine, but women hold a substantial portion of the traditional knowledge (Pourchez, 2014). Overharvesting of medicinal materials for commercial trade, however, can severely threaten plant populations and, subsequently, the longevity of traditional medicine (Moyo *et al.*, 2015).

In Nigeria, for example, biodiversity supports the health needs of millions, and studies have revealed hundreds of different kinds of herbs with a range of medicinal uses throughout the country (Nigeria, 2015). Accordingly, trade in medicinal plants and animal parts have grown, and now form a major category of merchandise in village markets in rural and peri-urban settlements. Consequently, maintaining health standards for millions of Nigerians depends on the protection and sustainable management of biodiversity. Efforts are now being made in different parts of the country to domesticate certain medicinal plants. For example, one of the mandates of the National Agency for Genetic Resources and Biotechnology is to document and archive essential genetic biodiversity resources.

In Central Africa, among some of the most valuable non-timber forest products in international trade are medicinal plants, supplying the pharmaceutical and herbal industries. For example, export of medicinal plants is a major foreign exchange earner in Cameroon, with annual earnings of $2.9 million (FAO, 2002). A number of species are exported, but the majority of the trade is in the following four species: *Prunus africana*, *Pausinystalia johimbe* (native to the coastal forests of Central Africa), *Voacanga africana* and *Strophanthus gratus* (Hoare, 2007). *Prunus africana* provides the largest volume of any African medicinal plant in international trade. It is most commonly used for its anti-inflammatory and analgesic properties, and to treat malaria. It is mainly exported from Cameroon, DRC, and Equatorial Guinea to Europe ranges (between 3,200–4,900 tons), with a market value estimated at $150 million/year. The commercial value of the trade in 1999 from Cameroon alone was estimated to be $700,000 within the country.

2.2.1.5. Water supply

Water is an important ecosystem service, and major sources of water in Africa include streams and rivers, freshwater lakes, and groundwater sources. Water security in much of the continent is, however, under threat, and a number of freshwater ecosystems are currently undergoing degradation due to deforestation, pollution, invasive species as well as climate change (Niang *et al.*, 2014).

After Australia (and Antarctica), Africa is the world's third-driest continent. It constitutes 15% of the global population, but only has 9% of the global renewable water resources, of which only 15% is groundwater (Figure 2.8), which supplies about 75% of its population. Water is also unevenly distributed, with Central Africa holding 50.66% of the continent's total internal water, and Northern Africa only 2.99% (Chapters 1 & 3). Thus, in all regions except Central Africa, water availability per person is lower than that of all of the world's other regions except Asia (the most populous continent) (UNEP, 2010). Since Africa's water resources are so vital to basic livelihoods and economic growth on the continent, an improved understanding of its availability, distribution and limitations is crucial for its better management (UNECA, 2006).

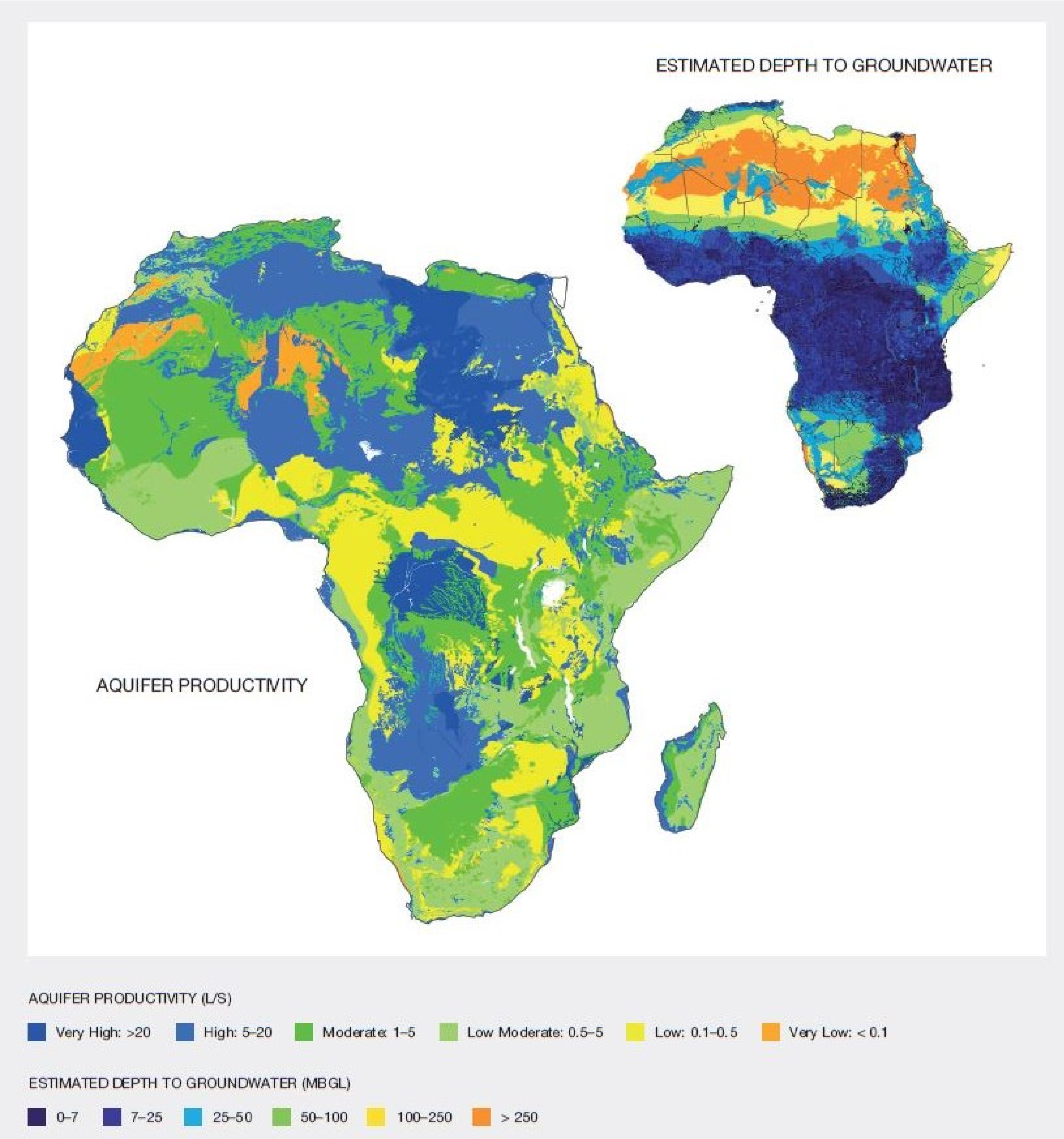

Figure 2.8: Aquifer productivity for Africa showing the likely interquartile range for boreholes drilled and sited using appropriate techniques and expertise. The inset shows an approximate depth to groundwater. Source: Bonsor *et al.* (2011).

An analysis of data from 35 countries in sub-Saharan Africa (representing 84% of the region's population) shows significant differences in water access between the poorest and richest fifths of the population in both rural and urban areas. Over 90% of the richest quintile in urban areas use improved water sources, and over 60% have piped water on premises. In rural areas, piped-in water is not accessed in the poorest 40% of households, and less than half of the population use any form of improved source of water (UN, 2012; Figure 2.9). Table 2.8 provides a more detailed breakdown of water availability in southern Africa.

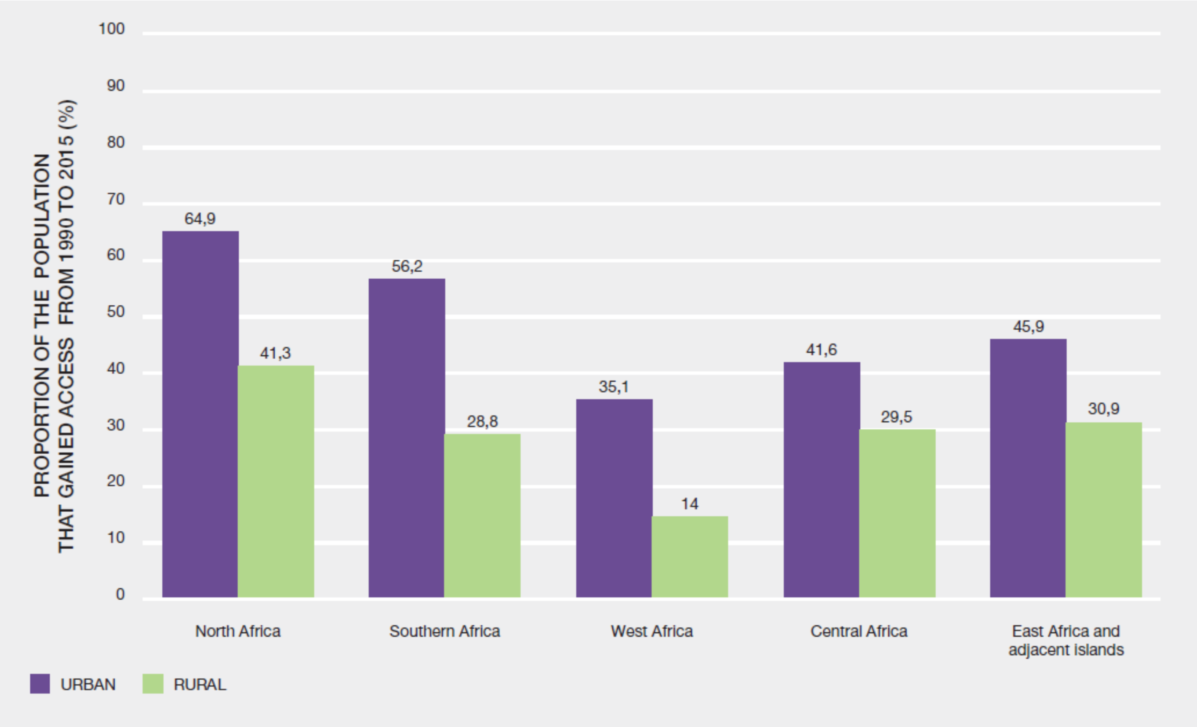

Figure 2.9: Population of Africa that gained Access to clean water since 1990 at urban and rural areas. Data source: UNEP (2016).

Table 2.8: Water availability and use in Southern Africa, as compiled in the South African Facilities Management Association regional scale study. Source: van Jaarsveld *et al.* (2005).

Country	Renewable water resources[1] (km^3/year)	Total water use (km^3/year)	Water per person[2] (m^3/person/year)	Access to improved water (% of total population)	Access to improved sanitation (% of total population)	Under-five mortality (per 1000 births)
Angola	184	0.34	13,620	38	44	260
Botswana	14.40	0.14	8,471	95	66	110
Burundi	3.60	0.23	519	78	88	190
Congo	832	0.04	26,8387	51	-	108
Dem. Rep. Congo	1,283	0.36	24,508	45	21	205
Equatorial Guinea	26	0.11	55,319	44	53	153
Gabon	164	0.13	130,159	86	53	90
Kenya	30.20	1.58	982	57	87	122
Lesotho	3.02	0.05	1,467	78	49	132
Malawi	17.28	0.11	1,641	57	76	183
Mozambique	216.11	0.64	11,960	57	43	197
Namibia	17.94	0.27	10,022	77	41	67
Rwanda	5.20	0.08	656	41	8	183

South Africa	50	15.31	1,156	86	87	71
Swaziland	4.51	0.83	4,215	48	44	149
Tanzania	91	2	2,642	68	90	165
Uganda	66	0.30	2,896	52	79	124
Zambia	105.20	1.74	10,233	64	78	202
Zimbabwe	20	2.61	1,560	83	62	123
Region		26.87[3]	11,390	61	63	155

- No data
[1] Total surface and groundwater resources (corrected for partial overlap) within a country's borders, plus or minus the natural flows entering and leaving the country, as well as flows secured through treaties and agreements with other countries. Aggregation cannot be done for the region as it would result in double counting of shared water resources.
[2] Population-weighted means.
[3] Weighted by total renewable resources of each country.

According to a survey of ecosystem services in seven African countries (Wong *et al.*, 2015), many regions in these countries are water stressed in terms of both supply and quality. The major causes of water degradation were cited as wetland degradation, agricultural, urban pollution, and deforestation. In the drier regions of Africa, oases play an important role in terms of both agricultural and water supply. Dates, cotton, olives, figs, citrus fruit, wheat and corn (maize) are common oasis crops. Amongst the world's most significant (and strategically important) supplies of groundwater exist beneath the Sahara Desert (Figure 2.8) for a relative amp of aquifer productivity in Africa) supporting about 90 major oases there. In certain areas, communities have traditionally planted trees such as palms around the perimeter of oases to protect against sand and wind erosion.

2.2.2. Regulating Contributions

2.2.2.1. Pollination, dispersal of seeds and other propagules

Pollination is an ecosystem service that is fundamental to plant reproduction, agricultural production and the maintenance of terrestrial biodiversity. Pollen is moved between flowers by wind, water, or animals as a precursor to fertilisation (IPBES, 2016). The majority of animal pollinators are insects, of which bees are the best known, but large animals such as birds, bats, and other mammals also frequently help pollinate large flowers. Pollination by hand has also been practiced for many years in, for example, the production of dates (*Phoenix dactylifera*) in the Middle East (Zaid *et al.*, 2002) and in the production of vanilla (Arditti, 1992; Fouche *et al.*, 1992).

African forest elephants (Chapter 3) are major seed dispersers. In Uganda, for example, elephants are responsible for spreading seeds a great distance from the parent trees. Asian elephants typically spread seeds from 1 km to 6 km, while Congo forest elephants are capable of spreading seeds as far as 57 km. *Myrianthus arboreus* are typical fruits targeted by large mammals and elephants in Congo (Campos-Arceiz *et al.*, 2011). Moreover, in the Congo Basin, *Baillonella toxisperma* (Sapotaceae), is species frequently exploited for a number of products, which relies on mammals and local populations for dispersal of the species (Duminil *et al.*, 2016). In Madagascar, insects, lemurs, birds, and bats play an important role in improving agricultural yield, pollination and forest regeneration (Oleksy *et al.*, 2017).

2.2.2.2. *Regulation of climate*

Ecosystem services play a critical role in mitigation and adaptation strategies for climate change. Forest ecosystems, in particular, contribute to mitigation, due to their capacity to remove carbon from the atmosphere and to store it. Effective agricultural management can also enhance carbon sequestration through soil conservation, or by introducing trees into agroforestry systems (Uprety *et al.*, 2012a). Well-managed ecosystems can further support adaptation to climate variability and change by providing a range of ecosystem services (Doswald *et al.*, 2014).

In cities, ecosystem based adaptation requires a robust understanding of landscape ecology and the potential of green infrastructure to improve the well-being of vulnerable communities, as in the case of Durban, South Africa (Roberts *et al.*, 2012). While ecosystem services are part of the solution to climate change, they are also, themselves, affected by changing climatic conditions (Chapter 3 & 4; SPM sections B & D). As a result, the provision of ecosystem services and the well-being of people that rely on these services are under threat by climate change. Such modification is expected to increasingly impact, both positively and negatively, the provision and value of ecosystem services.

Much attention has recently been focused on the role of Congo Basin forests in carbon sequestration & 4, and the impacts of deforestation and forest degradation on global carbon emissions. For example, estimates made in the 2008 State of the Forests Report (de Wasseige *et al.*, 2008; Nlom, 2011; Chapters 3 & 4) estimate the total stock of carbon in Congo Basin forests to be some 47 billion tons (Table 2.9). In key coastal and marine areas around the continent, climate change is increasingly impacting coral reefs and mangroves (Niang *et al.*, 2014; Chapters 3 & 4).

Table 2.9: Stock of carbon in Congo Basin forests (million tons). Source: de Wasseige *et al.* (2008); Nlom (2011).

	Cameroon	**Central African Republic**	**Congo**	**DRC**	**Equatorial Guinea**	**Gabon**	**Total**
Humid forests	3,203	886	3,263	18,056	383	4,033	29,824
Mosaic forest/croplands	414	167	534	1,945	57	287	3,404
Mosaic forest/savanna	628	2,437	145	3,059	3	20	6,292
Closed deciduous forest	6	54	73	1,625	0	10	1,768
Deciduous woodland	684	1,658	6	1,812	1	2	4,163
Open deciduous woodland	108	258	199	760	0	31	1,356
Total	5,043	5,460	4,219	27,258	445	4,383	46,808

Box 2.1. Regulating contributions by tropical rain forests

Major terrestrial ecosystems in the tropics are tropical rainforests and tropical savannas, basically separated by soil type and by period of the year when evapotranspiration is lower, the precipitation being 9–10 months for forests and 6–8 months for savannas, which define substantial differences in vegetation physiognomies. In other words, tropical forests cover an area of 17 million km^2 with 340 x 109 tons of Carbon stored in the above and below ground biomass, and tropical savannas cover 15 million km^2, with 24 x109 tons of Carbon. Therefore, tropical systems account for a substantial portion of the carbon stored in the atmosphere, highlighting the importance of these systems in the global carbon balance (IPCC, 2007).

2.2.2.2.1. Regulation of hazards and extreme events

Extreme climatic events, in particular droughts and heat waves, significantly impact on ecosystem carbon and water cycles and a range of related ecosystem services (Chapter 4, section 4.2.1.1). As indicated above, ecosystem services may help in regulation of hazards and extreme events.

For example, in terms of coastal resilience, mangrove forests provide protection and shelter against extreme weather events, such as storm winds and floods, as well as tsunamis. Mangroves absorb and disperse tidal surges associated with such events. As indicated by Hirashi *et al.* (2003), a mangrove stand of 30 trees per 0.01 hectares with a depth of 100 metres can reduce the destructive force of a tsunami by up to 90%. Recent research by The Nature Conservancy and Wetlands International proves that mangroves reduce wave height by as much as 66% over 100 metres of forest (McIvor, 2012).

Floods and fires are considered natural hazards—that is, natural processes or phenomena occurring in the biosphere that may become damaging for human as well as for natural systems. They are most strongly subject to feedback processes and most directly influenced by human activities such as urbanisation and environmental degradation (Chapter 4, sections 4.2.1.2 & 4.2.1.4). Deforestation, for example, has a direct effect on the incidence and magnitude of flood events (Schaeffer *et al*., 2013). Additionally, benefits from flooding may occur through the transport of sediments and nutrients to the coastal zone, although the consequences of this are often negative. Ecosystem conditions and their services can play a role in modulating both the event and the human systems that create conditions of vulnerability. This is also true for natural systems. The preservation of natural areas is important for flood attenuation. For example, some natural soils (not affected by human activities) have a large capacity to store water, facilitate the transfer of groundwater, and prevent or reduce flooding. The capacity to hold water is dependent on soil texture (size of soil particles and spaces between them) and soil structure. Wetlands, floodplains, lakes, and reservoirs are the main providers of flood attenuation potential in the inland water system.

For food production, Smith *et al.* (2010) have identified agricultural adaptation options that could have a positive impact on the mitigation of greenhouse gases emissions, such as measures that reduce soil erosion or increase the diversity of crop rotations. In the Economics of adaptation to climate change studies, the World Bank also identifies as options irrigation, improvement in water storage capacity and research and development to discover, for example, more drought-resistant species.
In terms of fisheries, sustaining affordable access to fish in the context of climate change will necessitate the adoption of adaptive measures aimed at protecting particular fish species or relieving fishing

pressure on specific species or areas (Cinner *et al.*, 2012). The survival of freshwater fish species, for example, can be aided by creating thermal refugia such as deep ponds or reducing freshwater abstraction from rivers, lakes, and ponds (Wilby *et al.*, 2010). A study by Merino *et al.* (2012) shows that the global population's demand for fish could be sustained through 2050 in a scenario of 2°C warming by that time, by increasing aquacultural production and supporting the sustainable management of marine fish stocks (Niang *et al*., 2014; Chapters 3 & 4).

For the energy access, increased frequency and intensity of droughts increased rainfall seasonality, and wet extremes, are projected to affect hydropower and thermo-electricity production. To mitigate the impacts of climate change on the energy sector, there is a need to simultaneously address both supply and demand. In terms of ensuring supply of energy, investment in renewable sources, which do not depend on hydropower and water-cooling systems–thereby avoiding exposure to climatic changes is necessary (Willmott *et al.*, 2011; Chapters 3 & 4).

2.2.2.3. Regulation of freshwater and coastal quality

Ecosystems influence the hydrological functioning of watersheds through their contribution to rainfall interception, evapotranspiration, water infiltration, and groundwater recharge. This influence can reduce the impacts of climate variation on downstream population. For example, ecosystems can preserve base flows during dry seasons if they facilitate groundwater recharge; they can also reduce peak flows or floods during rainfall events if they contribute to rainfall interception and infiltration. In addition, ecosystems can reduce soil erosion and landslide hazards, which are partially climate related (Locatelli, 2016). The function of the forest in regulating the flow of water is well known.

As described earlier, mangroves are coastal forests that lie on the crossroad where oceans, freshwater, and land realms meet; and are key in the regulation of freshwater and coastal quality (Chapters 3 & 4). They are among the most productive and complex ecosystems on the planet, thriving in salty and brackish conditions that would just kill ordinary plants very quickly. Their capacity to protect against storms and even sea level rise make them indispensable for coastal communities in their fight against climate change. African mangroves are home to very diverse fauna. Aquatic mammals include monkeys, antelopes, and manatees. Its roots and mud are home to molluscs, such as bivalves and oysters, and crustaceans. Live and decaying mangrove leaves and roots provide nutrients that nourish plankton, which in turn are food for many of these species. With this abundance of food, mangroves function as nurseries for many fish species; many of commercially caught fish have spent part of their lives in mangroves. Mangroves are also home to terrestrial fauna, including mammals, reptiles, and avian species; especially waterbirds (McIvor, 2012).

Mangroves also play a vital role in climate change mitigation and adaptation, as mentioned previously (Chapter 4, section 4.2.2.2). Ecosystems services related to climate change mitigation and adaptation include carbon sequestration at rates higher than terrestrial forest systems, a buffer against shoreline erosion, protection against extreme weather events through absorption and dispersion of tidal surges, and groundwater recharge. While estimates vary, many scientific studies have indicated that mangroves are among the most intense carbon sinks on the planet and that they sequester higher amounts of carbon than terrestrial forest ecosystems (Hutchinson *et al.*, 2014). Given the amount of carbon that mangroves sequester and the important socio-economic benefits derived from mangroves, Reduced Emissions from Deforestation and Forest Degradation activities-including conservation, sustainable management, and the enhancement of carbon stocks-have great potential to contribute to climate change mitigation efforts while providing economic development opportunities to the region.

In term of species, certain tree species could contribute indirectly to water regulation–in controlling pollution, for example. As an example, for water pollution control, suspension of the ground seed of *Moringa oleifera*, the benzolive tree, is used as a primary coagulant. It can clarify water of any degree of visible turbidity (ISO, 2016).

2.2.2.4. Soil amelioration

Soils play a pivotal role in major global biogeochemical cycles (carbon, nutrient, and water) while hosting the largest diversity of organisms on land. As a result, soils deliver fundamental ecosystem services. A soil process in support of one ecosystem service can either provide co-benefits to other services or result in trade-offs. The ability of soils to provide services is principally conferred by two attributes: the range of biogeochemical processes that occur in the soil, and the functionality of soil biodiversity (Smith *et al.*, 2015). As mentioned earlier, carbon storage is an important ecosystem function of soils that has gained increasing attention in recent years. Changes in soil carbon impacts on, and feedback to, the Earth's climate system through emissions of CO_2 and CH_4, as well as storage of carbon removed from the atmosphere during photosynthesis (climate regulation). Soil organic matter itself also confers multiple benefits, such as enhancing water purification and water holding capacity, protecting against erosion risk, and enhancing food and fibre provision through improved soil fertility (Pan *et al.*, 2013, 2014). Moreover, soil is an important carbon reservoir that contains more carbon (at least 1,500–2,400 PgC) than the atmosphere (590 PgC) and terrestrial vegetation (350–550 PgC) combined (Ciais *et al.*, 2013; Schlesinger *et al.*, 2013) and an increase in soil carbon storage can reduce atmospheric CO_2 concentrations (Whitmore *et al.*, 2014). After carbon, nitrogen is the most abundant nutrient in all forms of life, since it is contained in proteins, nucleic acids, and other compounds (Galloway *et al.*, 2008). Organisms ultimately acquire Nitrogen from plants, which on land is mostly taken up in mineral form (i.e., NH_4^+ and NO_3) from the soil. Soils further provide important ecosystem services through their influence on the water cycle. These services include provisioning services of food and water security, regulating services associated with moderation, and purification of water flows, and they contribute to the cultural services of landscapes/water bodies that support recreation and aesthetic values (Dymond, 2014). Furthermore, soils represent a physically and chemically complex and heterogeneous habitat supporting a high diversity of microbial and faunal taxa. These complex communities of organisms play critical roles in sustaining soil and wider ecosystem functioning, thus conferring a multitude of benefits to global cycles and human sustainability. Specifically, soil biodiversity contributes to food and fibre production and is an important regulator of other soil services, including greenhouse gas emissions, water purification (Bodelier, 2011).

Forest soils support the diversification of livelihoods and their role in providing ecosystem services which underpin the agricultural production system–through soil formation, nutrient cycling and provision of green manure and microclimate regulation; further enhancing synergies between the forest-tree landscape and the wider food production system (MA, 2005). Land clearing and slash-and-burn practices pose a particular threat to forests, mostly in the Eastern and Southern subregions (Chapters 3 & 4).

2.2.3. Non-material Contributions

Nature's non-material contributions are highly significant, even though their sources are intangible and based on cultural context. This section provides an overview of nature's non-material contributions in Africa, through highlighting the links between biodiversity, ecosystem services, spiritual, religious significance, and other immaterial services. The section further shows relevant cases of such contributions and the interrelations between these dimensions.

2.2.3.1. Supporting identities

Africa's cultural landscapes and habitats support religious and social experiences, according to Opoku (1978). Thus, the unseen is as much a part of reality as that which is seen. There is a complementary relationship between the two, with the spiritual seen as, in certain circumstances, more powerful than the material. A number of traditions and belief systems recognise linkages between health, diet, properties of different foods and medicinal plants, and horticultural/natural resource management practices–all within a highly articulated cosmological/social context (Edwards *et al.*, 1997). Table 2.10 below describes certain examples of supporting identities based on landscapes with religious, spiritual and social cohesion experiences in selected African countries.

Table 2.10: Selected case studies of landscapes being the basis for religious and spiritual and social cohesion in Africa.

Landscapes/seascapes, habitats or organisms	**Religious and spiritual linkages**	**Social cohesion linkages**
Kagore Shona people in Zimbabwe use burial grounds as sacred sites	Spiritual significance 'deeply embedded' in the cultural landscape (Matowanyika, 1997)	-
Loita Maasai's 'forest of the lost child' in Kenya	Spiritual forest among the Maasai	Direct expression of the relationship between communities and their habitats (Poole, 1993; Kakonge, 1995).
Wildlife products from Dryland areas in Nigeria (Adeola, 1992)	Wildlife products play important in the performance of spiritual rites (e.g., invoking and appeasing traditional gods and witches), and as constituents in traditional medicines or for aphrodisiac, fertility or potency purposes	Wildlife products play important roles in community ceremonies (e.g., funerals and installation of rulers)
Great Fish River Wetland in the AmaXhosa communities	Performance of spiritual rituals in wetlands sites to maintain a spiritual relationship with ancestors (Biggs *et al.*, 2004)	Wetland sites shape community's cultural identity
Wetlands in Niger Delta (James *et al.*, 2013) and in Cameroon (Feka *et al.*, 2008)	Deeply held spiritual values linked to wetlands in Nigeria and protected mangroves in Cameroon	-
Mountainous forest Mafa-Bécédi-brignan in Ivory Coast. (Kouassi *et al.*, 2008)	The sacred forest is seen as an ancestral heritage for the Akyé people and the site has a spiritual and religious significance to the people	The forest is used as a site for community festivals such as the generation day ("Fankwé") and the feast of yams (the "Yabe")

2.2.3.2. Physical and physiological experiences

Natural ecosystems in Africa provide significant opportunities for tourism, healing, relaxation, leisure, recreation, aesthetic appreciation, inspiration and education (e.g., hiking, recreational hunting, and fishing, birdwatching, snorkelling, gardening). Such services can improve mental and physical health; enhance a subjective sense of culture or place; and also enrich objective knowledge of natural and social sciences. Recently, Africa has been considered as one of the fastest growing tourism regions in the world. The continent holds more than a 5% share in tourism arrivals, and a 3.5% share of tourism receipts globally (UNWTO, 2017). 'Wildlife Watching Tourism' is considered a highly significant tourism segment in Africa. These activities can provide job opportunities for the local population through providing services to visitors, working as tour guides, staff, and cultural performers.

Ecotourism effectively managed by indigenous and local communities can promote biodiversity conservation and improve community development. Such positive outcomes are contingent, amongst others, upon improving the management and marketing skills of the local communities (Coria *et al.*, 2012). Botswana and Namibia provide (in certain sites) successful examples of how government policies that have banned commercial hunting and promoted community-based ecotourism have contributed to the conservation of wildlife and development of the local communities (Naidoo *et al.*, 2016).

2.2.3.3. Social relationships, spirituality and cultural identity

Natural ecosystems play a central role in cultural and spiritual practices for many indigenous and local communities in Africa, as indicated earlier. For example, Laikipia Maasai communities in Kenya are dependent on livestock for livelihoods and food security, which is dependent on the sustainability of a healthy environment. Spiritual leaders help the communities in interpreting variation in natural ecosystems, and advising in terms of response, including preparation for migration or shifting to new locations. Spiritual chiefs lead rituals and ceremonies to help the community connect with nature and remember the role of nature in the sustenance of life (Kaunga, 2016). These spiritual rituals involve, in many cases, the use of specific trees or species for their spiritual value. Many seeds and/or crops are critical during rituals and ceremonies (Kaunga, 2016; Mburu *et al.*, 2016).

As a further example, shellfish have an important patrimonial and symbolic value in Bijagos communities' culture, located in the island of Orango Grande, off the coast of Guinea, west of Africa. Shellfish are included in their religious ceremonies, as well as in other aspects of their life. For example, shellfish, along with other products such as tobacco, rice, or palm wine, is offered by the youngest to the oldest as a form of 'paying respect to the greatness of wisdom. Honey is also connected to the social life of these communities (Cormier-Salem *et al.*, 2010).

Studies have demonstrated relationships between biodiversity, human cultural, and linguistic diversity in Africa (Moore *et al.*, 2002). Aspects of cultural diversity include language, customs, habits, beliefs, local knowledge and practices used in the management of natural resources (Shemdoe, 2017). By being the sites of approximately 30% of the world languages, Africa is considered the richest worldwide in linguistic diversity, with more than 2,500 spoken languages (Batibo, 2006). Studies indicate, however, a decline in the African cultural and linguistic diversity (Batibo, 2006; Yankuzo, 2014). Effective management of natural resources and conservation of biodiversity of any cultural landscape require a better understanding of associated cultures, including linguistic diversity.

There is, thus, a growing recognition of the importance of protection of the different aspects of cultural diversity, including documentation of ILK of the respective local communities and the vernacular names bestowed on the species existing in the endangered cultural landscape (Yankuzo, 2014; Shemdoe, 2017; SPM sections A, B, & D). For example, efforts were made to record the cultural heritage of the Luhya people of the Kakamega region in Kenya to document vernacular bird names to improve conservation efforts of rare bird species (Sagita *et al.*, 1998).

2.2.3.4. Learning and inspiration

Nature on the African continent provides opportunities for gaining of knowledge and development of practices and skills for human well-being. One example here would be the development of ‘sensory ecology’ as a new scientific field in the 1940s by Felix Santschi, through his research studies on desert ants’ navigation in the Tunisian desert (Wehner, 1990).

As described previously, African indigenous and local communities have developed knowledge, practices, and experiences through their interactions with their biophysical environment, observing changes and dynamics of natural ecosystems; which have allowed them to respond to environmental changes and disturbances over time and space. Validation and integration of ILK have, to some extent, taken place in the pharmaceuticals sector through evaluation of the medicinal effectiveness of many plants used in folk medicine. This has led to the discovery and extraction of many bioactive secondary metabolites, many of which have been used for the production of effective drugs (Dias *et al.*, 2012; Mahomoodally, 2013).

There is a growing scientific recognition of the importance and merit of integration of ILK with conventional forms of knowledge to develop new knowledge systems for facing future challenges and coping with environmental changes, especially for the design of adaptation and mitigation strategies (Dias *et al.*, 2012; Gómez-Baggethun *et al.*, 2013; Chapter 1, section 1.3.2; SPM section A). There is significant potential for integration of ILK in sustainable agriculture practices, ecological restoration, land conservation and adaptive management of natural resource (Dias *et al.*, 2012). The incorporation of the ILK in the rehabilitation activities of degraded lands due to mechanised rain-fed agriculture in the southern Gadarif region in Sudan, for example, should successfully support improved rehabilitation (Sulieman *et al.*, 2012).

The agroforestry parkland system approach is one of several techniques for management of soil fertility adopted widely by local communities in Africa (Lesueur *et al.*, 1995). It is a dominant farming system that covers the majority of the cultivated area in the Sahelian countries in Africa. In this system, farmers grow their crops in combination with wild multipurpose trees. This system has supported farmers’ livelihoods for centuries. Farmers select and protect useful multipurpose species on their farmlands. The local farmers’ strategy is to simultaneously gain the advantage of collecting from wild plants resources while growing different crops, and benefiting from the enhancing effect that wild plants have on soil (Nikiema, 2005).

Proper selection of species to be used in ecological restoration activities is critical for successful restoration. Integration of ILK with scientific knowledge could facilitate selection of species with both ecological importance and traditional value, thus ensuring the effectiveness of the restoration activities (Higgs, 2005; Uprety *et al*., 2012a).

For crop selection, indigenous and local communities have developed land management approaches that depend on monitoring changes in wild plant species composition, particularly indicators of good soil quality. Farmers also use many species as indicators of poor soil condition, and as signs of land degradation. For example, local communities of Gadarif region in Sudan use the occurrence of species such as *Striga hermonthica*, *Veronica sp.*, *Evolvulus alsinoides*, *Desmodium dichotomum*, *Sonchus cornutus*, *Sorghum arundinaceum*, *Ocimum basilicum* and *Schizachyrium* in the agricultural land as indicators of land degradation (Sulieman *et al.*, 2012). In Niger, the presence of certain grasses such as the kounkoumbara (*Jacquemontia ovalifolius*), and the Tsintya (*Schoenfeldia gracilis*) is considered a sign of poor soil condition (Moussa *et al.*, 2008).

As a further example, farmers in Mpwapwa district of Tanzania rely on their traditional knowledge to determine soil quality, using a range of indicators such as soil colour and types of plants inhabiting the region. For example, the occurrence of Mahata (*Tragus berteronianus*) in a specific area is an indicator of soil suitability for growing maize, while the presence of Mphangalile (*Bidens lineoriloba*) is an indicator that the soil is suitable for growing groundnuts (Shemdoe, 2017). Certain native plants in deserts are also used as indicators of soil fertility. Local inhabitants in northern Sinai in Egypt, for example, consider the occurrence of the grass *Panicum turgidum* a sign of the fertility of the soil and they prefer to grow crops where the species occur (Halmy, 2016). In Niger, soils harbouring a high diversity of woody and grass species such as the *Guiera senegalensis*, *Piliostigma reticulatum*, *Andropogon gayanus*, *Cenchrus biflorus*, is considered as fertile soil (Moussa *et al.*, 2008).

For proper integration and dissemination of the ILK and traditional practices, comprehensive documentation of this body of knowledge is necessary (Bidak *et al.*, 2015; Halmy, 2016; Shemdoe, 2017). It is also important to translate the documented practices into national languages to make it accessible to researchers and decision-makers (Uprety *et al.*, 2012b; Shemdoe, 2017).

2.3. Geographical differences in production and contribution of ecosystem services

The particular location of Africa has contributed to the environmental conditions shaping the geographic distribution and the high diversity of its habitats and biomes (Chapters 1 & 4; SPM sections A & B). Chapter 3 to follow provides particular details in this regard.

2.3.1. Regulating contributions according to subregions and units of analysis

There are significant spatial differences with regard to regulating contributions of units of analysis (Table 2.10). Observed differences are closely linked to differences in spatial distribution of those ecosystems across African regions (MA, 2005; Chapter 3). The highest contribution of tropical and subtropical dry and humid forests to regulating nature's contributions to people is in West and Central Africa. East Africa and adjacent islands and Southern Africa share comparable regulating nature's contributions to people when we consider Mediterranean forests, woodlands, and shrubs (Chapter 3). The highest regulating nature's contributions to people of mountainous regions are derived mainly from the highest mountainous areas in Africa, namely East Africa and, to some extent, West Africa (Chapter 3). Regulating nature's contributions to people of tropical and subtropical savannas and grasslands is the highest in Southern Africa (Table 2.10). Their contribution to regulating nature's contributions to people in Central and North Africa is comparably low. Overall, most of Africa's subregions have some contribution to the regulating nature's contributions to people, irrespective of the unit of analysis, with the exception of North Africa for tropical and subtropical dry and humid forests (Table 2.11).

Across the five subregions in Africa (North, West, Central, East and South), human influenced areas have no significant regulating contributions. Urban and semi-urban areas, and cultivated areas (mainly intensive agriculture and livestock–see Chapter 3) have generally negative effects on climate and ecosystems through their contribution to the soil, air and water pollution and greenhouse gases emission. However, as mentioned earlier, carbon sequestration on agricultural lands is possible through a range of soil management strategies (Kane *et al.*, 2015).

Wetlands, including peat lands, mires, and bogs have good regulating contributions (flood moderation, climate regulation) respectively in Central Africa and East Africa (including the Great Lakes Region–see Chapter 3, and example in Box 2.2). Regulating contribution is moderate for West Africa wetlands, weak for Southern Africa and very weak for North Africa. Drylands and deserts, covering about 40% of the land of Northern Africa (MA, 2005), have a good contribution to carbon cycling and climate regulation while contributing moderately in West Africa, East Africa, and Southern Africa. Drylands store carbon at about the same rate as evergreen forests (Jaramillo *et al.*, 2003). In addition, deserts provide genetic resources in the form of many species adapted to aridity, excessive temperature, high salinity and other harsh condition.

Box 2.2: Water purification through wetlands: Nakivubo Swamps, Uganda

The Nakivubo swamps are adjacent to Uganda's capital city, Kampala. The local government had proposed draining the swamps to make way for agriculture, but when a study revealed that this ecosystem was providing a valuable service by filtering organic waste and other effluent derived from Kampala, the proposal was discarded. The study indicated that a water-purification facility capable of performing the same service would cost several million US dollars to construct, and $2 million/year to maintain. In this case, the value of converting land for agriculture would be offset by the cost of lost sewage-treatment capacity. Direct investment to maintain the wetland was a cost-effective measure to uphold the purification service. This example demonstrates how detailed information and cost estimates can better inform planning decisions.

Freshwater, Inland surface, Shelf ecosystems, Open ocean, Deep sea and Coastal areas are among instrumental ecosystems in Africa, with strong spatial variation regarding their regulating, material contributions and non-material contributions (Brown *et al.*, 2008, UNEP 2016). Because of their relatively wide distribution in East Africa and adjacent islands, wetlands (Chapter 3) and inland surface waters and water bodies/freshwater and shelf ecosystems (neritic and intertidal/littoral zone) provides excellent regulating contributions there, while moderate to weak contribution are observed in the other regions.

Deep sea areas of oceans constitute the so-called blue lungs of the planet, due to their highlighted role as global warming ‘regulator’. East Africa and adjacent islands, Southern Africa and West Africa are regions where this is mainly a factor. These regions contribute strongly to regulating contributions, as compared to the two other regions.

Table 2.11. Regulating nature's contributions to people according to subregions and ecosystem units of analysis.

ECOSYSTEM UNIT OF ANALYSIS		Regulating nature's contributions to people (water purification, climate regulation, or soil erosion regulation, etc.)				
		Subregions of Africa (from IPBES Africa regional assessment scoping document)				
		East Africa and adjacent islands	Southern Africa	Central Africa	North Africa	West Africa
		Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Mayotte, Reunion, Rwanda, Seychelles, Somalia, South Sudan, Uganda and United Republic of Tanzania	Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe	Burundi, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon and Sao Tome and Principe	Algeria, Egypt, Libya, Mauritania, Morocco, Sudan, Tunisia and Western Sahara	Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo
TERRESTRIAL	Tropical and subtropical dry and humid forests				NA	
	Mediterranean forests, woodlands and shrub					
	Tundra and High Mountain habitats					
	Tropical and subtropical savannas and grasslands					
	Drylands and Deserts			NA		
	Wetlands – peatlands, mires, bogs					
	Urban/Semi-urban areas					
	Cultivated areas (including cropping, intensive livestock farming, etc.)					
AQUATIC	freshwater, brackish and marine					
	Inland surface waters and water bodies/freshwater					
	Shelf ecosystems (neritic and intertidal/littoral zone)					
	Open ocean pelagic systems					
	Deep-Sea					
	Coastal areas intensively and multiply used by human					

FORESTS- WOODLANDS – SAVANNAS - GRASSLANDS

Excellent contribution	Good contribution	Moderate contribution	Weak contribution	Very weak contribution	Non applicable
Excellent contribution	Good contribution	Moderate contribution	Weak contribution	Very weak contribution	Non applicable
Excellent contribution	Good contribution	Moderate contribution	Weak contribution	Very weak contribution	Non applicable

2.3.2. Material contributions according to subregions and units of analysis

The material contribution is the highest for West, East Africa and adjacent islands, when tropical and subtropical dry and humid forests are taken into account (MA, 2005; Box 2.3; Chapter 3). This is further observed for woodlands, shrubs and Tropical and subtropical savannas and grasslands. However, a moderate and low contribution is noticed for these four major ecosystems when we consider tundra and high mountain habitats (Table 2.12). North Africa shows globally the same tendency for all units of analysis, and has a relatively low contribution to material services.

Box 2.3: Case study of material contribution in Miombo and Mopane (Malawi)

Miombo and Mopane woodlands are the dominant land cover in southern Africa. Nature's contributions to people from these woodlands support the livelihoods of 100 million rural people and 50 million urban dwellers, and others beyond the region. Material contributions to rural livelihoods are estimated to $9 ± 2 billion/year; 76% of energy used in the region is derived from woodlands; and traded woodfuels have an annual value of $780 million. Woodlands harbour a unique and diverse flora and fauna that provides spiritual succour and attracts tourists (Ryan *et al.*, 2016).

Regardless of the region, urban and semi-urban areas have very weak to no material contribution in term of provisioning ecosystem services (Chapter 3). For West, East, and Southern regions of Africa, cultivated areas have good material contribution through provisioning of biofuel crops, animal waste, fuel wood, agricultural residue pellets, and food from domesticated organisms, amongst others. In regions of African Great Lake (East Africa and adjacent islands and Central Africa) and in West Africa, wetlands, peatlands, mires, and bogs have excellent contribution through provisioning of drinking water, irrigation water, hydro-power, fishes, minerals, and fuels (Upton *et al.*, 2013). Drylands and desert have a low material contribution in West, East, and Southern Africa while having moderate material contribution through provisioning food, fibre, forage, medicinal plants, wood fuel and biochemical; fresh water; hydrocarbons (oil and gas); metals and metallic minerals; precious minerals etc.

Freshwater, brackish and marine contributions are well distributed in East Africa and adjacent islands (http://www.zonu.com/fullsize-en/2009-11-07-10918/African-Wetlands.html; Chapter 3), where they strongly contribute to material contributions. In Central Africa and West Africa, their contribution is moderate, while weak in Southern Africa and North Africa, with the exception of the contributions from the Nile River to the livelihood of the people in Egypt and Sudan. Similar patterns are observed for inland surface waters and water bodies/freshwater contributions.

Table 2.12: Material nature's contributions to people according to subregions and ecosystem units of analysis

ECOSYSTEM UNIT OF ANALYSIS		Regulating nature's contributions to people (Functional and structural aspects of organisms and ecosystems that modify environmental conditions experienced by people, and/or sustain and/or regulate the generation of material and non-material benefits, such as soil formation, pollination, seed dispersal, fresh water regulation, air quality regulation, etc.)				
		Subregions of Africa (from IPBES Africa regional assessment scoping document)				
		East Africa and adjacent islands	Southern Africa	Central Africa	North Africa	West Africa
		Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Mayotte, Reunion, Rwanda, Seychelles, Somalia, South Sudan, Uganda and United Republic of Tanzania	Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe	Burundi, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon and Sao Tome and Principe	Algeria, Egypt, Libya, Mauritania, Morocco, Sudan, Tunisia and Western Sahara	Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo
TERRESTRIAL	Tropical and subtropical dry and humid forests				NA	
	Mediterranean forests, woodlands and shrub					
	Tundra and High Mountain habitats					
	Tropical and subtropical savannas and grasslands					
	Drylands and Deserts					
	Wetlands – peatlands, mires, bogs					
	Urban/Semi-urban areas					
	Cultivated areas (including cropping, intensive livestock farming, etc.)					
AQUATIC	freshwater, brackish and marine					
	Inland surface waters and water bodies/freshwater					
	Shelf ecosystems (neritic and intertidal/littoral zone)					
	Open ocean pelagic systems					
	Deep-Sea					
	Coastal areas intensively and multiply used by human					

FORESTS- WOODLANDS – SAVANNAS - GRASSLANDS

Excellent contribution	Good contribution	Moderate contribution	Weak contribution	Very weak contribution	Non applicable
Excellent contribution	Good contribution	Moderate contribution	Weak contribution	Very weak contribution	Non applicable
Excellent contribution	Good contribution	Moderate contribution	Weak contribution	Very weak contribution	Non applicable

2.3.3. Non-material nature's contributions to people according to subregions and units of analysis

Non-material contributions refer to contribution to people's subjective or psychological quality of life, individually and collectively as defined in the update on the classification of nature's contributions to people by the IPBES (IPBES/5/INF/24). West and Central Africa show the highest value for non-material contributions, especially for tropical and subtropical dry and humid forests. For North Africa, this does not apply for most biomes, except for Mediterranean forests, woodlands, and shrub. Eastern, Southern, and Central Africa, on the other hand, show high contribution for non-material services as regards tropical and subtropical savannas and grasslands (Table 2.12). Importance of non-material provisions in sustaining remaining forests has been reported (UNEP, 2016). Neglecting cultural values and services in the design of interventions can produce dire unintended consequences and can impede the achievement of program goals. For example, West (2006) documented how marketing cultural forest goods in Papua New Guinea, an economic-development strategy to offset the consequences of conservation interventions, overlooked the numerous ways in which local peoples used the land and how wildlife contributed to their sociocultural system (Chan *et al.*, 2012).

For all regions of Africa, urban and semi-urban could have a very low contribution in term of non-material services (Chapter 3). With regards to cultivated areas, they have a moderate non-material contribution. These areas are also of high interest to researchers. In terms of wetlands, peatlands, mires, and bogs, good non material contribution is evident, especially in West Africa, Southern Africa, Central Africa and East Africa and adjacent islands, where they represent important sites for cultural activities (Adams, 1993; Verschuuren, 2010), for eco-tourism (Crisman *et al.*, 2001) and for research.

Apart from North Africa, where drylands and deserts are culturally integrated (Davis, 2004), these biomes have a low non material contribution in the other regions of Africa. Certain communities, particularly in North Africa, have lived in deserts for millennia. These communities ranged in their activities from hunter-gatherers, agriculture, and pastoralism. In Africa, deserts have contributed extensively to global culture, traditions and the body of scientific knowledge (Ezcurra, 2006). Deserts provide opportunities for spiritual and recreational contributions.

Table 2.13: Non -material nature's contributions to people according to subregions and ecosystem units of analysis

	ECOSYSTEM UNIT OF ANALYSIS	Non-material nature's contributions to people –Many cultural ecosystem services as defined in the Millennium Ecosystem Assessment. Subregions of Africa (from IPBES Africa regional assessment scoping document)				
		East Africa and adjacent islands	Southern Africa	Central Africa	North Africa	West Africa
		Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Mayotte, Reunion, Rwanda, Seychelles, Somalia, South Sudan, Uganda and United Republic of Tanzania	Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe	Burundi, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon and Sao Tome and Principe	Algeria, Egypt, Libya, Mauritania, Morocco, Sudan, Tunisia and Western Sahara	Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo
TERRESTRIAL	Tropical and subtropical dry and humid forests					
	Mediterranean forests, woodlands and shrub					
	Tundra and High Mountain habitats					
	Tropical and subtropical savannas and grasslands					
	Drylands and Deserts					
	Wetlands – peatlands, mires, bogs					
	Urban/Semi-urban areas					
	Cultivated areas (including cropping, intensive livestock farming, etc.)					
AQUATIC	freshwater, brackish and marine				?	
	Inland surface waters and water bodies/freshwater					
	Shelf ecosystems (neritic and intertidal/littoral zone)					
	Open ocean pelagic systems					
	Deep-Sea	NA	NA	NA	NA	NA
	Coastal areas intensively and multiply used by human					

FORESTS- WOODLANDS – SAVANNAS - GRASSLANDS

Excellent contribution | Good contribution | Moderate contribution | Weak contribution | Very weak contribution | Non applicable

Excellent contribution | Good contribution | Moderate contribution | Weak contribution | Very weak contribution | Non applicable

Excellent contribution | Good contribution | Moderate contribution | Weak contribution | Very weak contribution | Non applicable

2.4. Status, trend, future dynamics of Nature's Contributions People (NCP)

2.4.1. Status of NCP

The status, trends and future dynamics of contributions of nature to people in Africa are diverse but also depend on the underlying drivers and subregional/national level understanding, interpretation and integration of NCP into land-use and nature conservation (Chapters 3 & 4). The underlying drivers of status, trends and future dynamics of NCP include natural direct drivers relating to non-human processes and activities, whose occurrences are beyond human influence including natural climate and weather patterns, as well as extreme events such as prolonged drought or cold periods, tropical cyclones and floods, glacial lake outburst floods, earthquakes, volcanic eruptions and tsunamis (Chapter 4, sections 4.2.1.1 & 4.2.2.2). Anthropogenic direct drivers are those which result from human decisions and actions, such as institutions and governance systems, and other indirect drivers including degradation, exclusion and restoration of terrestrial and aquatic habitats, intensification or abandonment, harvesting of wild populations, climate changes produced by urbanisation and industrial emissions, pollutions of soil, water or air due to population pressures and species introductions (Chapter 4).

These underlying factors affect contributions of nature to people in different aspects, including climate regulation, disturbance regulation, water regulation, water supply, erosion control and sedimentation retention, soil formation, nutrient cycling, waste treatment, biological control, food production, raw materials, genetic resources, recreation and cultural heritage (Chapter 4). This Assessment uses the African subregions including North Africa, West Africa, Central East Africa and adjacent islands, and Southern Africa as ecosystem units of analysis. Such an approach is due to the level of understanding and interpretation of how NCP in public policy at the national, subregional and regional level play a significant role in biological diversity and ecosystem services. The methodology adopted in this section was to use the IPBES' categories of NCPs, and identify specific indicators as representations in the African subregions.

2.4.1.1. Habitat creation and maintenance

Protected areas are specifically earmarked and devoted areas of land or sea for the conservation and maintenance of biodiversity including natural and associated cultural resources, often governed through legally established systems. Chapters 3, 4 and 6 provide substantively more detail in this regard (Chapter 1; SPM sections B, D, & E).

2.4.1.2. Dispersal of threat potentials

The relationships among invasive alien species, terrestrial, freshwater and marine environments play significant roles in the status of nature's contributions to people. The introduction of invasive alien species causes changes to water regulation, waste treatment, weed control, water supply, erosion control and sedimentation retention, food production, recreation, and genetic resources (United Republic of Tanzania, 2014; Chapter 4, section 4.2.2.4). The status of nature's contributions to people is also affected by utilisation of biodiversity. Further details on this are provided in Chapter 4. Common challenges on the continent are over-fishing/harvesting and hunting inhibiting food production, biological control, genetic resources and availability of raw materials (Chapters 3 & 4).

A range of policies and strategies have been developed to support forests on the continent to be able to contribute to the regulation of hazards and extreme events (Fasona *et al.*, 2015, 2016; Chapter 6). Despite the progress in developing climate change policies in many African countries, a number have not reached the implementation stage, let alone made clear progress on mainstreaming (Chapter 6; SPM section E).

2.4.2. Trends of nature's contributions to people

2.4.2.1. Habitat Creation and Maintenance

In sub-Saharan Africa, both national and international (as well as regional) initiatives have resulted in the growth of protected areas (Chapter 4, section 4.5.1; SPM sections B, D, & E). For example, in 1998, Equatorial Guinea developed their protected area extension network from 3,196 to 5,081 km^2, representing about 18.1% of the national land area (Machado, 1998).

Despite challenges to protected area creation and management (Chapters 4 & 6), the establishment of protected areas can procure a net benefit in terms of total economic value (Table 2.14). For instance, in West Africa, the comparison of the total economic value of ecosystem services within marine protected areas and ecosystem services located in non-protected zones (comparative area) shows that, while the direct use value (associated with fish and wood production mainly) is higher in a non-managed area, since there is no limitation on extractive activities, the indirect use value associated with carbon sequestration, fish biomass production, water purification and coastal protection against erosion is higher in marine protected areas than in the comparative area indicating a better quality and quantity of ecosystem services. This benefit is largely due to the better health status of ecosystems in marine protected areas that can be assimilated to a better resilience capacity in face of global changes (Bonin, *et al.*, 2016).

Table 2.14: Benefits of ecosystem protection; an example of marine protected areas in West Africa. Source: Failler *et al.* (2012).

	Marine protected areas*($ million)	Comparative areas*	Benefits
Direct use value	11.2	20.4	-9.1
Indirect use value	39.5	28.8	10.6
Non-use value	0.5	0.6	-0.1
Total	**51.1**	**49.8**	**1.3**

*based on the same surface (MPA surface as reference)

2.4.2.2. Materials and assistance

Chapters 3 and 4 provide detail on status and trends in deforestation, land transformation and losses due to, for example, poaching and unsustainable offtake (SPM section B). For example, in Southern Africa, the main concern over ivory poaching is in Mozambique, where the combined elephant population in the Selous-Niassa Ecosystem lost an estimated 7,000 elephants in the period between the 2009 and 2011 surveys (European Union, 2016).

2.4.2.3. Regulation of threat potentials

As described previously, and in more detail in Chapters 3 and, most particularly, 4; Africa is expected to be particularly severely impacted by climate change (SPM section B). Impacts on ecosystem services are already evident, with, in certain cases, future impacts likely to be severe (Niang *et al.*, 2014; Chapters 3 & 4; SPM section B). Impacts of invasive alien species (IAS) have already been referred to in Chapter 1, and are covered in detail in Chapter 4 (Chapter 4, section 4.2.2.4.3; SPM sections B & D).

IAS are currently already impacting nature's contributions to people and ecosystem services, a trend that is likely, in certain areas, to worsen in the future (Chapter 4, section 4.2.2.4.3; SPM sections B & D).

2.4.3. Future Dynamics of nature's contributions to people

A range of international frameworks (Chapters 3, 4, & 6; SPM sections C, D, & E) have highlighted the importance of identifying, designating and managing protected areas as fundamental to biodiversity and ecosystem in relation to nature's contributions to people. Important indicators include the proportion of protected areas in relation to total land area and by type of ecosystems, as well as progress made by regions/subregions/countries with regards to implementation of international policies on natural resource use, protection and monitoring (Chapters 5 & 6; SPM sections C, D, & E). The future dynamics of nature's contributions to people in Africa could be influenced by both direct and indirect activities in the proportion of protected areas relative to the total land area and by type of ecosystems, progress made by regions/subregions/countries with regards to implementation of international policies on natural resource use, protection and monitoring (Chapter 4, sections 3.5.2 & 3.5.3).

The future dynamics of protected areas in Africa are likely to depend on the following strategies (Chapters 4, 5 & 6):

- Economic and land tenure reform strategies: Progress in privatisation and commercialisation of protected areas will be improved by land ownership and tenure security which guarantees long-term investments and productivity. It should also create an inclusive financial environment that is accessible to all. Efforts to strengthen national and regional land governance towards protected areas is an imperative (Chapter 6).
- Landscape-wide conservation planning: a broad-based picture of conservation strategies which integrate protected areas into development goals covering all biomes, sectors, and subregions will be more useful in achieving development goals.
- Resolving conflict: Policy and legislation should address competition from other land-uses and between local communities and nature conservation programmes by exploring and emphasising co-dependence rather than competition. It should also build and nurture regional groups, transboundary arrangements, and collaborations among neighbouring protected areas (Chapter 6; SPM section E).
- Community-Based Natural Resource Management: (Chapters 1 & 6; SPM section E).
- Strengthening the governance capacity of protected area institutions to address the complex interactions between natural resources and local communities focusing on site-based planning and management of protected areas as well as promoting equity and benefit-sharing. This should also include measures to prevent and mitigate potential negative impacts and threats (Chapter 6; SPM sections D & E).

2.5. Impact of nature's contributions to people changes on human well-being

As shown in this and other assessments, human driven activity is altering the structure and functions of landscapes, water bodies and climate, and biogeochemical cycles, with some of the worst case scenarios in the tropics (Foley *et al.*, 2005; MA, 2005; Chapter 4). African biodiversity and ecosystems are currently undergoing massive structural changes (MA, 2005; Daily *et al.* 2009; Effiom *et al.*, 2013c; Chapters 3 & 4,). A change in ecosystem structure implies a change in ecosystem functioning (Lavorel *et al.*, 2012); and, ultimately, the provisioning of ecosystem services, nature contributions to human that enhance human well-being and good quality of life (Chapters 3 & 4). The strong dependence of human on nature contributions through biodiversity and ecosystem services is evident on the African continent, as detailed in this chapter. The concept of sustainably utilising ecosystem services is thus gaining considerable attention globally, since it conveys the idea that ecosystems are socially and economically valuable, and vital in human well-being, in addition to their ecological value. This section will look at the impact of such change on basic material for good life, health and social security.

2.5.1. Impacts of changes in contributions of nature on basic material for a good life

Changes in nature's benefit to people influence all components of human well-being, especially the basic material needs for a good life. Environmental degradation caused by various drivers and through different pathways (Chapter 4) endangers provisioning of the basic material for human well-being.

Along with biodiversity erosion, as detailed in Chapters 3 and 4 to follow, we face erosion of indigenous and local knowledge, as mentioned earlier (SPM section B). The decline in ILK has a number of implications for biodiversity conservation efforts since, without an adequate understanding of the natural ecosystems and knowledge about natural resources, future local and rural communities will be challenged in maintaining these resources (Grainger, 2003; Solh *et al.*, 2003; Heneidy *et al.*, 2007). For example, local communities in the coastal desert of Egypt used to be traditional nomadic communities. Such communities have been subjected to changes due to urban encroachment and development activities over the last three decades. Such activities influenced the demographic structure and the nomadic lifestyle of local inhabitants. Abandonment of traditional practices threatens the sustainability of the indigenous local knowledge, since younger generations prefer to engage in the new economic activities (e.g., construction of coastal resorts, real-estate businesses, intensive agriculture, and quarrying activities) to the traditional practices (e.g., herding, rain-fed agriculture, collection of medicinal plants, amongst others) (Bidak *et al.*, 2015; Halmy, 2012; Halmy *et al.*, 2015a; Halmy *et al.*, 2015b & c). This may have led to a decline in number of the ILK holders in these communities.

Similar challenges to communities' traditional life ways have been recorded by Kaunga (2016) in Maasai community in northern Kenya, where the changes in land ownership and land-use due to developmental projects challenge the Maasai and Samburu communities to maintain their traditional lifestyle and associated indigenous local knowledge. The transfer of the ILK to the new generation has declined in these communities due to these socio-economic changes. Attempts have been made by the Samburu communities, as a response to the reduced attention to the traditional activities in favour of the new economic activities; through diversification of livelihood sources by include activities that would benefit from their ILK such as ecotourism (Oguge, 2016).

2.5.2. Impacts of changes in contributions of nature on people's health

There is a growing recognition worldwide of the crucial links between health and the natural environment. The linkages between biodiversity, ecosystem, ecosystem services (its conservation, sustainable use, status, trend, and degradation) and human health are increasingly taking centre stage in conservation and policy discussion in many parts of the world (SPM sections B & E). The issue has become more prominent following decisions at the 12th Conference of the Parties to the Convention on Biological Diversity in October 2014, which encouraged Parties to "consider biodiversity and health linkages in the preparation of national biodiversity strategies and action plans, development plans and national health strategies" (UNEP, 2014). This is due to the fact that, as mentioned earlier, many raw materials for the pharmaceuticals are tied to the conservation and sustainable use of certain plant or animal species or genetic resources (Kretsch *et al.*, 2016). In many traditional communities, watersheds and some rare species and special habitats that have high medicinal value or contribute to climate and water regulation have been inadvertently preserved by their status as sacred sites. Similarly, nature through biodiversity and ecosystem services contribute significantly to dietary health, mental health, emerging infectious diseases, in medical research, and the use of sentinel species in health risk assessments, (see Chivian *et al.*, 2008; Keune *et al.*, 2013; CBD Secretariat *et al*., 2015).

The assessment of the impact of the change in ecosystem services on health is critical because when health is affected, there is bound to be a cascading effect on the other aspects of well-being such as quality of life, livelihood security and freedom of action. According to Kretsch *et al.* (2016), apart from the many recognised connections between ecosystems and health, health comprises a major element of self-reported assessments of personal (subjective) and population (objective) measures of well-being, with health status also affecting personal perceptions of the other aspects of well-being. Additionally, health and health care delivery are also some of the most significant areas of national, regional and local government activity and expenditure. Since ecosystems may be viewed as "settings" in which health is determined or important determinant of human health (Horwitz *et al.*, 2011; Myers *et al.*, 2013), quantifying the impact of change of nature (biodiversity and ecosystem) on health is, therefore essential to provide insights to the nature and extent of the impact, as well as cascading effects on other aspects of well-being (Chapter 4, section 4.4.4.3.1). There is, however, in certain circumstances, a paradox in that some major changes to natural systems have been associated with public health benefits. For example, early efforts to reduce malaria in certain parts of sub-Saharan Africa (Keiser *et al.*, 2005) by draining swamps that were habitats for mosquito vectors was for the eradication of malaria, while certain deforestation, dams, and irrigation projects been to increase the supply of food and clean energy—critical building blocks for public health (Keiser *et al.*, 2005; Myers *et al.*, 2013).

2.5.3. Impacts of changes in contributions of nature on livelihood security

The decline in biodiversity and ecosystem services is resulting in more variable ecological dynamics, the decline in nature contributions to humans, and more human exposure to catastrophic hazards and diseases and increasing loss of livelihoods, especially to marginalised communities in the tropics especially in Africa (Chapters 3 & 4). It, therefore, implies that sustainably managed ecosystems that enhance the continuous flow of ecosystem services are vital to sustaining human well-being, as both are mutually beneficial (SPM section E). It is becoming clear that promoting the conservation of one ecosystem service, (for example, in safeguarding watersheds to maintain water regulation), a bundle of other ecosystem services will be provided such as prevention soil and soil nutrient erosion (Maukonen *et al.*, 2017), thus showing positive synergies (Chapter 6; SPM section E). For example, according to Effiom (2013b), 95% and 86% of primate-dispersed trees utilised by rural households provide fruit and/or nuts and other non-timber forest products, respectively, showing that these trees are significantly very important for human sustenance (Chapter 3). This study corroborates previous findings from other studies from the African region (Fa *et al.*, 2006; Kone *et al.*, 2008) in terms of a general reliance on forest resources, such as bushmeat, fruits and/or nuts, medicinal plants, timber and other non-timber forest products, including firewood as source of livelihood (Chapters 3 & 4). The take home message here is that structural and functional change to biodiversity which diminishes nature's capacity to contribute benefits to human will impact negatively on livelihood security. This impact becomes particularly prominent in localities that lacks provision of alternative livelihood options and /or viable adaptive measures to combat environmental change. It, therefore follows that achieving human livelihood security especially that in the developing world, will depend greatly on achieving environmental security (Biggs *et al.*, 2014).

Environmental security is a component of 'Environmental Livelihood Security (ELS). The concept of ELS encompasses a balance between natural resource supply, nature contribution to people, and human demand on the environment to promote sustainable livelihood (Biggs *et al.*, 2014). ELS describe the challenges of maintaining global food security, universal access to freshwater and energy to sustain livelihoods and the promotion of inclusive economic growth, whilst sustaining key environmental systems functionality. Maintaining this balance poses a significant challenge, as shown earlier and in Chapters 3 and 4 to follow, as livelihood activities contribute in many instances to the undesirable transformation of natural ecosystems (Chambers *et al.*, 1992). The interactions between environmental changes and the effect of human utilisation for livelihood is enormously complex. Hence in 1992, the UN Conference on Environment and Development adopted the term sustainable livelihoods, as a means of linking socioeconomic and environmental concerns (Brocklesby *et al.*, 2003), stressing that degradation of ecosystem services could be significantly slowed or reversed if the full socioeconomic value of ecosystem services were taken into account in policy planning and decision-making (Chapter 6; SPM sections A & E).

2.5.4. Impacts of changes in contributions of nature on people's freedom

Freedom and, in most cases, the ability to make choice(s) cannot exist without the presence of the other elements of well-being–including human basic needs of food, shelter, clothing, and income. Nature contributions to people through the different forms of ecosystems services (supporting, provisioning, regulating, and cultural) underpin human well-being (MA, 2005). Degradation of natural ecosystems that limits nature's capacity to contribute to the supply of these elements of well-being has an indirect negative impact on human freedom of choice or action. This has been evident throughout the continent - for example, conditions such as degraded natural forest may lead to a poor harvest of non-timber forest products, and, ultimately, result in a substantial loss of livelihood (Chapter 3).

The impact of change on nature contributions to human well-being is bound to adversely constrain the actions of the poor, whose economic and social sustenance depend greatly on the services of natural systems. Conversely, people living in countries with effective environmental governance, where, for instance, energy, quality education, and safe drinking water are affordable and accessible, can exercise and maintain freedom. There are currently limited studies providing evidence as to how a change of ecosystem structure and services may impact human freedom, a research gap that requires prioritisation. This section thereby recognises the need for improved research to grant a better understanding of the impact of impacts of the alteration of the ecosystem on livelihood, health, and freedom, to better inform decision-making in the land-use planning, biodiversity and nature conservation and resource allocation for the attainment of total well-being for a man in the African region.

2.6. Negative nature's contributions to people

As mentioned in Chapter 1 and throughout this chapter thus far, nature provides benefits for human well-being (MA 2005; IPBES, 2016). It should be noted, however, that not all nature`s contributions are positive; some are negative with adverse impacts on human well-being (Lukamba, 2010). Certain studies refer to contributions by ecosystems that are perceived to have a negative impact on human well-being as ecosystem disservices (Lyytimäki *et al.*, 2009; von Döhren *et al.*, 2015). For instance, the decimation of large primates in hunted tropical forest is associated with a lower richness of seedlings for large-seeded trees that are dispersed by primates, and a higher richness of seedlings for small-seeded species that are dispersed abiotically or by other animals (Nunez-Iturri *et al.*, 2008; Effiom *et al.*, 2013c;

Effiom, 2013a; Chapter 3). Plant richness may significantly affect the way in which ecosystems function, which may, in turn, determine the provisioning of certain ecosystem services (Lewis *et al.*, 2004; Bunker *et al.*, 2005; Brodie *et al.*, 2009; Lavorel *et al.*, 2012). Hunting may cause community-level shifts along the leaf economics spectrum (Wright *et al.*, 2004), with significant effects on processes such as herbivory, litter decomposition, and soil fertility and productivity (Lavorel *et al.*, 2012). In other cases, ecosystem disservices may result from inappropriate land-use, such as the incorrect application of fertilisers and pesticides, increasing cultivation on slopes and overuse and harvest (Power, 2010; Escobedo *et al.*, 2011; Firbank *et al.*, 2013; von Döhren *et al.*, 2015; Chapters 3 & 4).

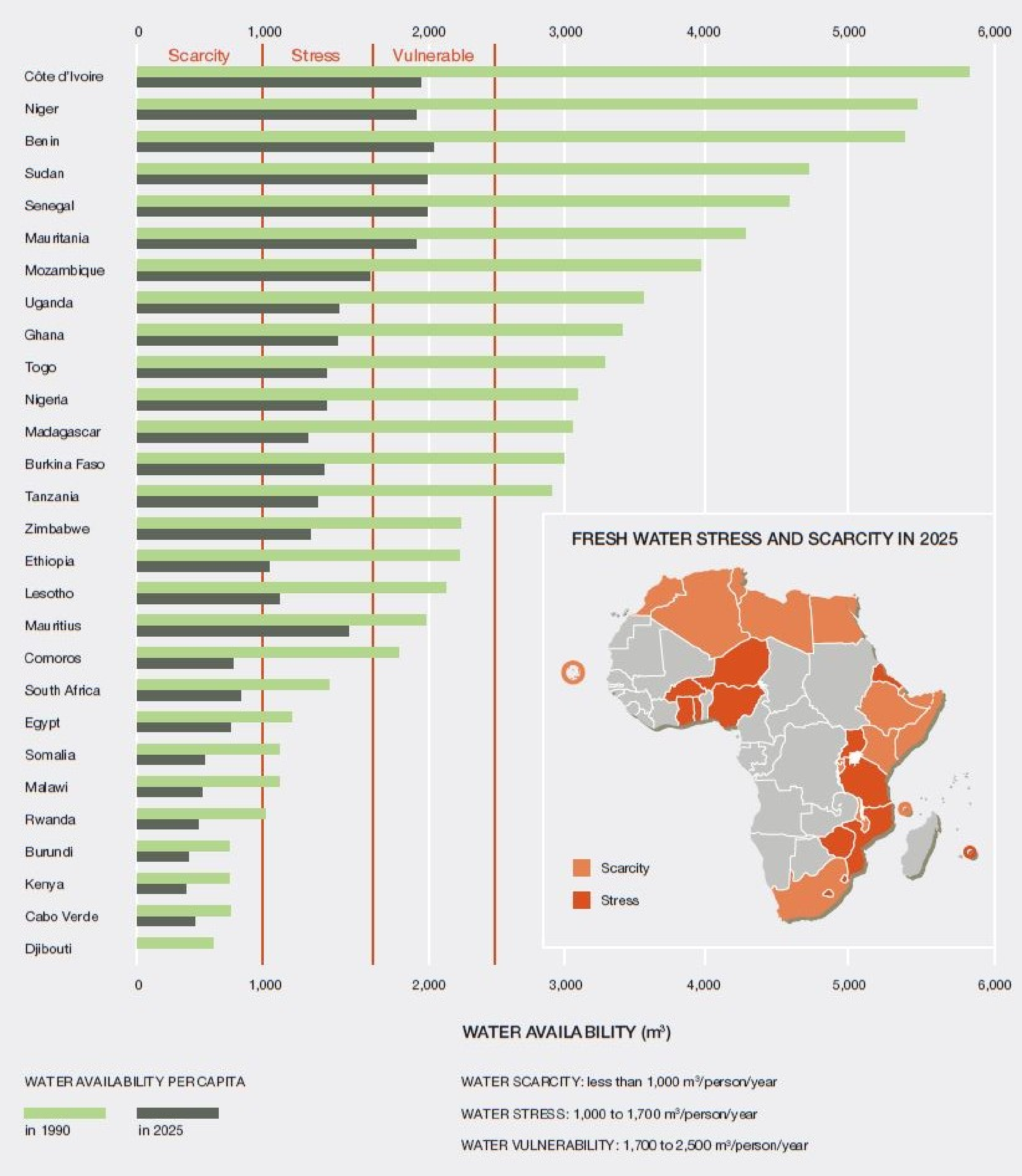

Figure 2.10: Water crisis in Africa. Source: UNECA (2005).

Chapter 4 (Section 4.2.1.4) provides more detail on natural disasters; and the role of natural ecosystems in impact and/or driver. For example, the provisioning of material contributions, other than food that is central to human well-being, is also very difficult to realise under drought conditions–water security providing a particularly critical example in this regard (Figure 2.10).

2.7. Conclusion

African ecosystems provide material, non-material and regulating nature's contributions to the people of Africa and the world. Material contributions are the provisioning services that describe the material or energy outputs from ecosystems. The materials considered in this section are food, energy, health and water. Food production serves as an important material contribution of ecosystem services in terms of nature's contributions to people. Many communities in Africa depend on food provided by natural ecosystems such as forests, grasslands, wetland areas and water bodies sustaining fisheries for their food security. The main food items that are sourced come from bushmeat, insects, fresh fruits, nuts, seeds, tubers and green leafy vegetables, edible oils, drinks spices, condiments, mushrooms, honey, sweeteners, wild tubers, and snails, amongst others. Fuelwood is the dominant source of energy in Africa, with over 90% of energy needs in rural areas supported by fuel wood. Urban areas rely more on charcoal as source of energy for cooking and demand for household energy from rapidly growing urban centres exerts massive pressure on forests. Up to 80% of the population in Africa rely on traditional medicine to help meet their primary health care needs. Furthermore, numerous plant products are used in traditional African medicine. Nature's non-material contributions from land- and seascapes provide important areas for recreation, relaxation, healing, nature-based tourism and aesthetic enjoyment, religious and spiritual fulfilment, cognitive development, as well as the promotion of social cohesion and a sense of identity. Tourism is well developed and an important source of income in northern, southern, and eastern parts of Africa as well as the oceanic Islands. Many sites in Africa have been classified as protected or heritage sites for their non-material contributions. Regulating contributions from nature are increasingly being appreciated and valued higher in national accounting systems. Highly valued services are mainly linked to agricultural production, including climate, air and water regulation, disease and pest control and pollination. Other services include nesting, feeding and mating sites for birds and mammals, e.g., the Important Bird and Biodiversity Areas.

The true value of biodiversity and nature's contributions to human well-being tend to be under-appreciated in decision-making processes in Africa, particularly for non-material and regulating contributions. Existing studies on the valuation of biodiversity and nature's contributions to people in Africa are few and limited in both geographical scope and the types of ecosystems covered. Valuation of biodiversity and its contributions to people is a tool used in decision-making and in communicating their importance to humanity, thus serving as support for their conservation and sustainable use as well as the sharing of benefits from the utilisation of biological resources. Knowing the value of biodiversity components and their contribution to people can thus encourage investments for their management through the most appropriate methods, and assist in assessing the trade-offs between different policy options as well as the cost and benefits of biodiversity conservation and use policies. Failure to reflect values in decision-making often results in unsustainable use and depletion of biodiversity and ecosystem services. Valuation of biodiversity and nature's contribution to people has received limited attention across Africa. More studies were conducted in coastal and marine areas, inland waters and forests than in the other ecosystems. Most value studies were conducted in Southern Africa and East Africa and adjacent islands than in other subregions on the continent.

By taking into account the economic value of the whole range of ecosystem services, including the ones that don't have a market value per se (water purification, coastal protection, etc.), valuation studies have shown that many ecosystems have a higher overall value when kept in their pristine or optimal health condition than used for material purposes such as timber production. For instance, tropical forest and mangrove have a value 4 times higher when maintained for providing services such as carbon sequestration, non-timber material provisioning, etc. than use for timber production only. Therefore, valuation should be conceived as a tool to guide policy and management decision-making. Overall, policy interventions should be devoted to the maintaining or restoration of an optimum health status of the all ecosystem as well as an optimum use. This will guarantee the resilience of African ecosystem against global changes.

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Chapter 3: Status, trends and future dynamics of biodiversity and ecosystems underpinning nature's contributions to people

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Executive summary

Africa has rich and varied biological resources forming the continent's natural wealth on which its social and economic systems are based *(well established).* Africa is home to almost one-quarter of the world's mammal species with their 1,160 species, including 194 species of primate and 91 species of antelope. It also has more than 2,500 species of birds–one-fourth of the world's total–and at least 5,445 species of fish, as well as 2,121 reptile species. The African mainland harbours between 52,000 and 73,000 plant species and about 150,000 known species of insects are known for sub-Saharan Africa. Nine of the world's 35 biodiversity hotspots are in Africa {3.3.1, 3.4.1, 3.4.2, 3.4.3, 3.4.4, 3.4.5}.

Most, if not all, terrestrial ecosystems in Africa have already experienced major biodiversity losses in the past 30 years, which has negative impacts nature's contribution to people. The prospect is that this trend will continue in the future *(established, but incomplete)*. Africa's highly diverse terrestrial ecosystems, ranging from forests to arid/semi-arid ecosystems are being threatened by the increasing change in land-use, for example, conversion to agriculture and deforestation, leading to habitat fragmentation and destruction. Poaching and illegal trade has resulted in the significant decline of many species of wild fauna and flora, which has, for example, resulted in the near extinction of the wild northern white rhinoceros. To compound this, climate change will likely cause a 5–8% increase in arid/semi-arid lands and endanger 25–40% of mammal species in national parks. Forty-four million hectares of lowland humid forests, representing 25% of the total forest area, are under timber-harvest concession which negatively impacts biodiversity in these hotspots. For example, the Congo Basin is the second largest rainforest after Amazonia and includes more than 10,000 vascular plant species, many of them endemic to the region. These losses can affect local community's access to forest products such as medicinal plants and wild fruits {3.4.1.1, 3.4.2.1, 3.4.3.1, 3.4.4.1, 3.4.5.1}.

Freshwater biodiversity in Africa is currently under severe threat with an estimated 10% decline expected by 2050 *(established but incomplete)*. The inland waters of Africa support a high diversity of aquatic life. Highest levels of biodiversity are found in the Rift Valley Great Lakes (Lake Malawi, Lake Tanganyika, and Lake Victoria) and in the rivers of the Congo. Among 4,989 freshwater species assessed (fish, crabs, mollusc, dragonflies, aquatic plants), 21% are threatened within Africa and 91% endemic. The majority of threatened species are found in areas with high levels of development and demand on water resources, mainly along the Mediterranean and Atlantic coasts of Morocco, Algeria and Tunisia, in Upper and Lower Guinea, southern and eastern South Africa and in the Great lakes in eastern Africa. It is predicted that by 2050s, hydrological conditions for 80% of freshwater fish species will be substantially different from present-day conditions. Freshwater species are essential for supporting livelihoods, as 45% of fish and 58% of plant species are regularly harvested {3.4.1.2.2, 3.4.2.2.2, 3.4.3.2.2, 3.4.4.2.2, 3.4.5.2.2}.

Much of Africa's complex and unique marine and coastal biodiversity are increasingly threatened *(established but incomplete)*. The wide continental shelf along the northwest coast of Africa, mangrove forests of West and East Africa and adjacent islands, provide diverse habitats that support high levels of biodiversity of fish and invertebrate species. The Red Sea has a high degree of endemism and is an important repository of marine biodiversity including 12 of the world's 60 seagrasses, and 38 coral reef genera with 220 species. Africa contains 19% of mangrove cover, however, approximately 20–30% has been lost in the past 25 years, with average deforestation rates of 2%/year. With overexploitation, habitat degradation and loss, acidification, pollution from land-based sources, invasive alien species and sea level rise, highly valuable ecosystem services are being threatened {3.4.1.2, 3.4.2.2, 3.4.3.2, 3.4.4.2, 3.4.5.2}.

Current losses of genetic biodiversity due to climate changes and unsustainable resource exploitation in Africa are restricting future management and development options *(unresolved)*. Information on genetic diversity in Africa is largely lacking. However, few existing studies on genetic diversity have shown reduced genetic diversity of domesticated plant and animal species and of wild species. Modern crop varieties have also led to the decline in genetic diversity of traditional plants or crops, as out of the quarter million plant varieties available for agriculture, only 3% are in use. This includes large-scale monocultures such as 200,000 km^2 being used for industrial crops like sugarcane. Of the 150 indigenous breeds of African cattle, 47% are threatened, and 22% at risk of becoming extinct. Species with very specific habitat needs and or are climate sensitive (e.g., mountain gorillas and cheetahs) are especially under threat as the populations become increasing isolated through land-use transformation and climatic change {3.5}.

Healthy ecosystems can reduce socioeconomic vulnerability by supporting well-being *(well established)*. Healthy ecosystems are conserved socio-ecosystems, including those managed by communities, thanks to their knowledge of local environmental and socio-ecological conditions (cf examples from Indigenous Local Knowledge Task Force). Restored socio-ecosystems are beneficial for biodiversity recovery and livelihoods {3.5}.

Increases in protected areas and new conservation strategies are needed to curtail current unprecedented rates of biodiversity loss *(established but incomplete)*. The extent of protected areas in Africa has almost doubled in the last decades; protected areas now cover 14% of Africa with 4,358,096 km^2 in terrestrial area covered by protected areas and 345,917 km^2 in marine areas. Effectiveness of protected areas is poor in many areas due to a combination of factors, such as: climate change, overexploitation (over-hunting, logging, livestock herding), civil conflicts, and encroachment from local populations to sustain their livelihoods, and inadequate park design and administration. Land-grabbing is a major risk of environmental injustice and local communities' exclusion. The importance of transboundary protected areas and corridors is especially obvious for migratory species new governance types of protected areas, managed by local communities, are recognised and diffused all over African regions (cf Mangagoulack Indigenous and Community Conserved Area in Casamance). New financial and legal mechanisms for the preservation of ecosystem services (biodiversity offset, REDD+, PSE) are expanding, and provide emerging opportunities {3.3.3.1, 3.3.3.2}.

3.1. Introduction

This chapter synthesizes the status, trends and future projections of biodiversity and ecosystems, and their positive and negative effects on the provision of key ecosystem goods and services that contribute to economic growth, livelihoods and human well-being in the African region. The Assessment is based on a review of recent (past 10–15 years) scientific publications, reports and databases, and focuses on status and trends at the regional scale and on a subregional level covering East Africa and adjacent islands, West, Central, North and Southern Africa as classified by the United Nations. Some case studies using key species that are important for the functioning of ecosystems and livelihoods are also presented. For much of Africa, biodiversity is key to the delivery of nature's contributions to people. It is for that reason that the current trends of biodiversity decline have serious implications for economic growth, human well-being and livelihood security.

African ecosystems and biodiversity are biologically and ecologically unique, attract substantial tourism revenue, and provide significant ecosystem services at local, regional and global levels. However, the rates of biodiversity loss and ecosystem degradation are increasing. Under business-as-usual scenarios, it is predicted that a further 11% of biodiversity would be lost (OECD, 2008). Fifty-five species are extinct, with 1,781 threatened with extinction (Brooks *et al.*, 2016a). According to the IUCN Red List, 21% of the 4,539 freshwater species assessed in Africa are threatened. Ninety-one per cent of these freshwater species are endemic to the African continent and are therefore also globally threatened (Darwall *et al.*, 2011). Twelve per cent of birds, 19% of mammals and 26% of amphibians are threatened (Darwall *et al.*, 2011). From 1990 to 2015, Africa has experienced the biggest forest area loss compared to the rest of the world except South America. The rate of forest loss in Africa has decreased substantially in the past five years, average per capita forest area declined from 0.8 hectares to 0.6 hectares per person (FAO, 2015a).

In recent times, much effort has gone into designating protected areas in Africa, with the hope of saving areas of crucial importance for biodiversity conservation (UNEP-WCMC, 2008). As a result, for example, forested areas within protected areas in Africa have increased up to 4,133,459 km^2 from 2003 to 2015, representing about 14% of the total area (Brooks *et al.*, 2016a). In total, Africa contains 8,338 protected areas, including 374 marine protected areas, 44 natural World heritage sites, 72 Biosphere reserves, and 381 Ramsar sites (UNEP-WCMC *et al.*, 2017).

In order to achieve an effective and thorough documentation of the status, trends and future of biodiversity and ecosystem services in this region, it is essential to consider the unique history of African continent. For the human species (*Homo sapiens*), Africa provides many examples of human impacts–positive or negative–that point to the past, current and future of biodiversity and ecosystem services. Historically speaking, archaeologists have established that Olduvai archaeological grounds in Serengeti was one of the homes to earliest hominids, the human ancestors who relied on and interacted with the natural environment over two million years ago (Domínguez-Rodrigo *et al.*, 2009; Beverly *et al.*, 2014). Based on recent scientific findings, Africa was also a home to *Homo naledi*–presumably one of the closest members of the human family–*H. erectus*, H. *habilis* and ultimately *H. sapiens* (Callaway, 2015). As such, it is indisputable that Africa is one of the earliest locations for understanding how humans developed the culture of using ecosystem services. For example, oil palm (*Elaeis guineensis*, Least Concern) is an economic plant native to Africa and was introduced to Southeast Asia in the 19th century, where it has now become a source of both economic prosperity and ecological concern (Hai, 2002). That said, it is important to add that the commodification of biodiversity and ecosystem services pose serious risks to long-standing African management systems that view humans as inseparable part of biodiversity (Gerber *et al.*, 2007). Indeed, some studies found that upland areas of the East African Rift Valley system have helped in preserving plant species DNA for a period of up to 5,000 years (Boessenkool *et al.*, 2014). In Africa it is not only the physical environment that preserve biodiversity, but also social and economic systems that are well-connected to biodiversity and ecosystem services (Gerber *et al.*, 2007). Presently, there are increasing concerns over how human impacts, changing institutions, science and policy, habitat fragmentation, modernisation and urbanisation are undermining the present and future sustainability of biodiversity and ecosystem services in Africa (Anderson *et al.*, 2013; McGuinness *et al.*, 2014). As the Anthropocene age begins, it is imperative for scientists and policymakers to revisit strategies that will support transformation towards a better future that secures biodiversity, ecosystems and human well-being and prosperity.

3.2. Methods and information sources

Status, trends and future dynamics of biodiversity were examined at genetic, species and ecosystem levels. The genetic variations/trends within populations (see for example the FAO status of world genetic resources for food and agriculture and International treaty on plant genetic resources was used), and at the species and communities levels, indicators such as relative abundance, richness and uniqueness of species and their diversity including; wild relatives, threatened species, species vulnerability to climate change and other pressures etc. were examined. Sources of information about indicators include multi-lateral environmental agreements on biodiversity such as Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and Convention on Migratory Species. Other sources of information include Summaries from State of Biodiversity in Africa, and Digital Observatory for Protected Areas.

The criteria that Chapter 3 used to evaluate species status and trends cover seven main questions: i) What are the data resources? ii) What are the biome-specific evaluation levels? iii) For what taxonomic groups is it important to have data? iv) What does present status mean and how can it be evaluated? v) What are the past trends – timescales and evaluation techniques? vi) What are the future dynamics of biodiversity looking towards the 2020 Aichi Biodiversity Targets (Chapters 4 and 5), and vii) What are the gaps? The seven overarching questions given above factored in: Habitats/ecosystems/landscapes, their extent and conditions relating to the ecosystem services that they provide. Ecologically and biologically significant areas, Important Bird Areas/Key Biodiversity Areas, hotspots, protected areas/Biosphere reserves/Ramsar sites, World heritage sites, fragile and vulnerable areas, degraded lands, agricultural lands; marine and other aquatic areas; land cover types, elevation zones, etc. The major ecosystem units of analysis taken into account are: deserts and drylands, savanna and grasslands, tropical dry and humid forests, mountains, islands and linear coastal systems, wetland and freshwater systems, urban and semi-urban systems, aquaculture-agriculture-sylviculture. Possible case studies include: Mountain Gorilla, Cheetahs, Fish of East African rift lakes, Mopane worms, Mangroves, Palms, *Ficus*, and Argan (*Argania spinosa*).

Presentation of the status and trends of key biodiversity features in focal case studies, covering both trends in the extent and quantity of key biodiversity components that play an important role in ecosystem structure and function or have iconic or spiritual/cultural value. Trends in quality and condition of biodiversity features crucial to the services/benefits/values highlighted in Chapter 2 and Chapter 4, including small-scale features with special ecological and cultural significance. ILK of the status and trends of biodiversity were documented through published literature and dialogue workshops undertaken in the context of IPBES to complement scientific methods and studies (Roué *et al.*, 2017). Trends in invasive species and their impacts were also examined.

3.3. Overview of status and trends of biodiversity in the African region

3.3.1 Status of species diversity

The African region holds an incredibly rich and unique flora and fauna containing over a quarter of the world's biodiversity, with the greatest concentrations occurring in the African equatorial ecosystems, South Africa and Madagascar (UNEP-WCMC, 2016; Table 3.1; Figure 3.1). The African region contains between 52,000 and 73,000 plant species (Schatz, 2002; UNEP, 2008), including 20% of the world's tree diversity (9,000–11,000 species) (Slik *et al.*, 2015). Madagascar has about 11,000–13,000 species of vascular plants, of which 90% are endemic (Gautier *et al.*, 2003). Africa is home to over one-quarter of the world's 5,450 mammal species. It also has more than 2,500 species of birds–one-fifth of the world's total–and at least 5,445 species of fish, alongside 1,134 described amphibian species (UNEP, 2008, UNEP-WCMC *et al.*, 2016). Southern Africa alone has at least 580 families and about 100,000 known species of insects, spiders, and other invertebrates (UNEP, 2008). The African region also stands out for holding 40% of the global diversity of primate species (194 species), from human's closest relative, the chimpanzee, to the unique and diverse lemurs of Madagascar (Schwitzer *et al.*, 2013). While the rest of the globe underwent massive Pleistocene extinctions of large-bodied vertebrates (megafauna), Africa maintains an almost intact assemblage (Gill, 2015; Ripple *et al.*, 2016). These megafauna act as ecosystem engineers and play important roles in maintaining ecosystems (Malhi *et al.*, 2016).

As also indicated in Chapter 1, there are eight recognised biodiversity hotspots in the African continent (Cape floristic region, Coastal forests of eastern Africa, Eastern Afromontane, Guinean forests of Western Africa, Horn of Africa, Madagascar and the Indian Ocean islands, Maputaland Pondoland Albany, and Succulent Karoo) plus the Mediterranean Basin which encompasses part of the Northern Africa and Southern Europe (Mittermeier *et al.*, 2004; Conservation International, 2011; Table 3.3).

Table 3.1: Comparison of African regional freshwater biodiversity assessments. Source: Darwall *et al.* (2005); Smith *et al.* (2009); Darwall *et al.* (2009); García *et al.* (2010); Brooks *et al.* (2011).

	Central Africa	**East Africa and adjacent islands**	**West Africa**	**North Africa**	**Southern Africa**
Number of taxa	2261	1661	1395	877	1279
% Threatened	15%	26%	14%	28%	7%
% Critically endangered	2.47%	2.25%	2.29%	7%	1.87
% Endangered	5%	7.5%	4.2%	8%	2.65
% Vulnerable	7.29%	16%	7.5%	13%	2.81
% Data deficient	21%	13%	16%	14%	15%

Table 3.2: Estimated numbers of species by major taxonomic group. Source: Darwall *et al.* (2005); Darwall *et al.* (2009); Smith *et al.* (2009); García *et al.* (2010); Brooks *et al.* (2011); http://amphibiaweb.org; http://reptile-database.reptarium.cz/).

Taxon	**Central Africa**	**East Africa and adjacent islands**	**West Africa**	**North Africa**	**Southern Africa**
Fishes	1,440	1,090	542	128	355
Mollusca	241	230	90	155	116
Odonata	504	304	287	82	272
Crabs	44	37	35	3	19

Amphibians	303	390	150	61	221
Mammals	22	135	16	126	13
Water birds	198	868	380	200	221
Turtles	4	N/A	3	8	15
Aquatic plants	435	N/A	472	509	N/A

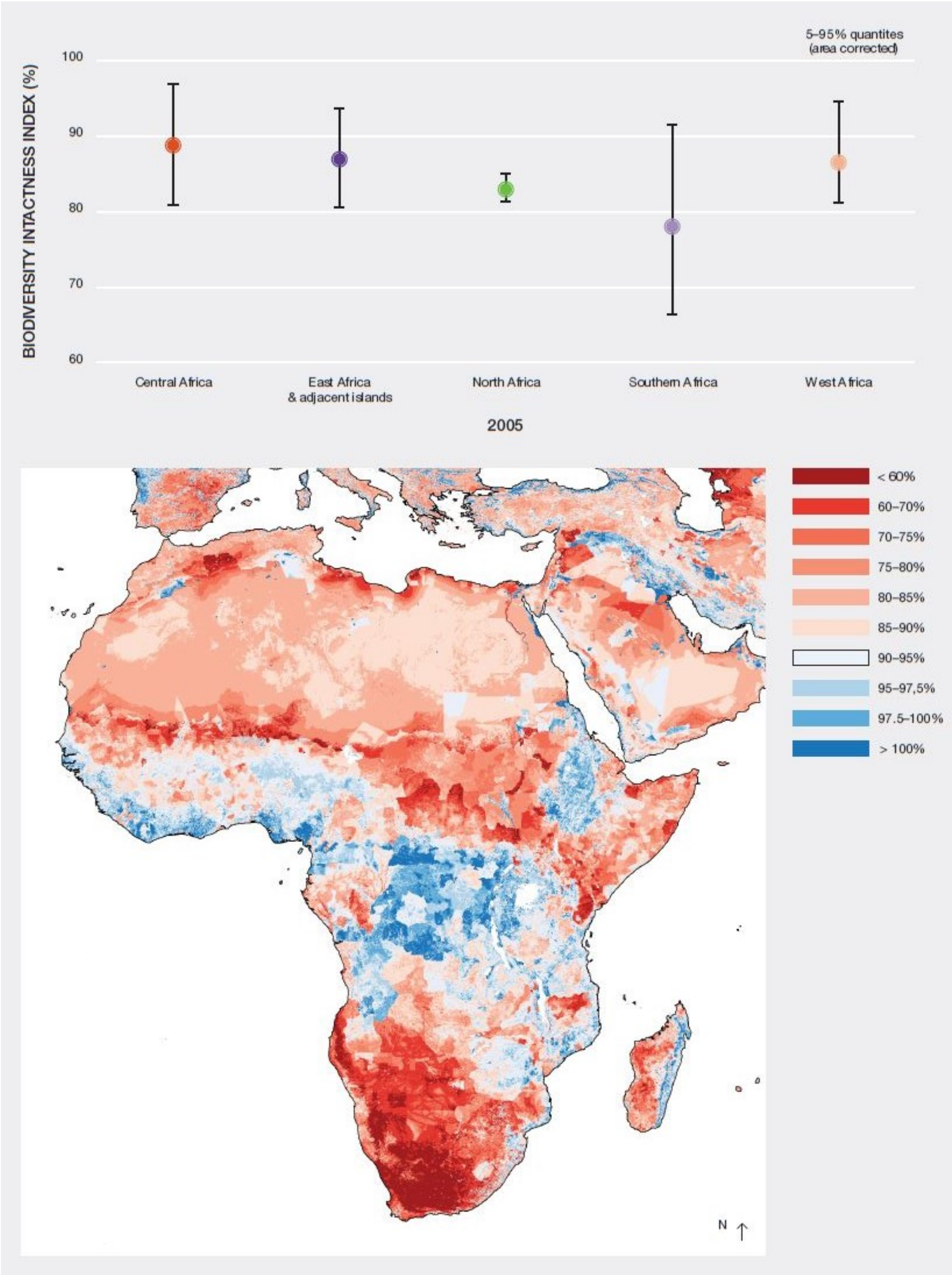


Figure 3.1: Biodiversity Intactness Index: The map and chart show the remaining populations of native species as a percentage of their original populations. From the map, blue areas are within proposed safe limits for the maintenance of ecosystem health, whereas red areas are beyond the safe limit. Source: Map from Newbold *et al*. (2016), and chart from GEO BON-PREDICTS, the figure prepared by Task Group on Indicators and Knowledge and Data Technical Support Unit.

Table 3.3: Biodiversity hotspots in Africa and their biological values.

Hotspots		Area (km^2)					Threatened Endemic biodiversity			
	Human population density ($people/km^2$)	Original extent	Vegetation remaining	Protected area	Protected area: categories I-IV *	Endemic plant species	Birds	Mammals	Amphibians	Extinct species §
Cape Floristic Region	51	78,555	15,711	10,859	10,154	6,210	0	1	7	1
Coastal forests of eastern Africa	52	291,250	29,125	50,889	11,343	1,750	2	6	4	0
Eastern Afromontane	95	1,017,806	106,870	154,132	59,191	2,356	35	48	30	1
Guinean forests of western Africa	137	620,314	93,047	108,104	18,880	1,800	31	35	49	0
Horn of Africa	23	1,659,363	82,968	145,322	51,229	2,750	9	8	1	1
Madagascar & the Indian ocean islands	32	600,461	60,046	18,482	14,664	11,600	57	51	61	45
Maputaland Pondoland Albany	70	274,136	67,163	23,051	20,322	1,900	0	2	6	0
Succulent Karoo	4	102,691	29,780	2,567	1,890	2,439	0	1	1	1
Mediterranean basin[¥]	111	2,085,292	98,009	90,242	28,751	11,700	9	11	14	5

§ Recorded extinctions since 1500.
€ Categories I-IV affords higher levels of protection.
¥ The Mediterranean Basin expands from west to east from Portugal to Jordan and north to south from northern Italy to Morocco. Apart from the African States which are Morocco, Egypt, Libya, Tunisia and Algeria, it includes also parts of Spain, France, the Balkan states, Greece, Turkey, Syria, Lebanon, Israel, as well as around five thousand islands scattered around the Mediterranean Sea. West of the mainland, the hotspot includes the Macronesian Islands of the Canaries, Madeira, the Selvages (Selvagens), the Azores, and Cape Verde

3.3.1.1 Threat status

The IUCN Red List of Threatened Species has been disaggregated from the global scale by Brooks *et al.* (2016a & b) for the Africa region, and these data are presented below (Table 3.4; Figure 3.2). Taxonomic groups for which comprehensive global assessments (>90% of species) have been done, were used. For these taxa, Brooks *et al.* (2016a & b) report an estimated 1,781 threatened species in the Africa region, representing 19% of the total number of extant species within these taxa. Of the 5,016 endemic species found in the region 23% are threatened with extinction (Figure 3.2). The greatest proportion of threatened species are found in East Africa and adjacent islands with 17% of extant species considered threatened including 43% of the endemics occurring in the subregion. This is in part due to the high number of threatened endemic species in the regions hotspots, e.g., the Eastern Arc Mountains and coastal forests of Tanzania and Kenya (Gereau *et al.*, 2016), as well as those in Madagascar and the Indian Ocean Islands. Central Africa, however, has the highest proportion of threatened endemics at 50%. North Africa has the lowest proportion of threatened species (9%) and southern Africa the lowest proportion of threatened endemics (23%). Trends in the IUCN Redlist Index over the last 28 years indicate that West Africa has the highest relative annual contribution to the overall change in the global Red List Index for the taxa assessed within the region and this is true in particular for amphibians. For mammals the highest relative annual contribution in the region came from Central Africa, whilst for birds it came from Southern Africa (Brooks *et al.*, 2016a). Considering the number of data deficient taxa, this number could be as high as 35% for the region with endemic threat status in Central Africa potentially being as high as 67%, highlighting the need for greater efforts to protect these taxa.

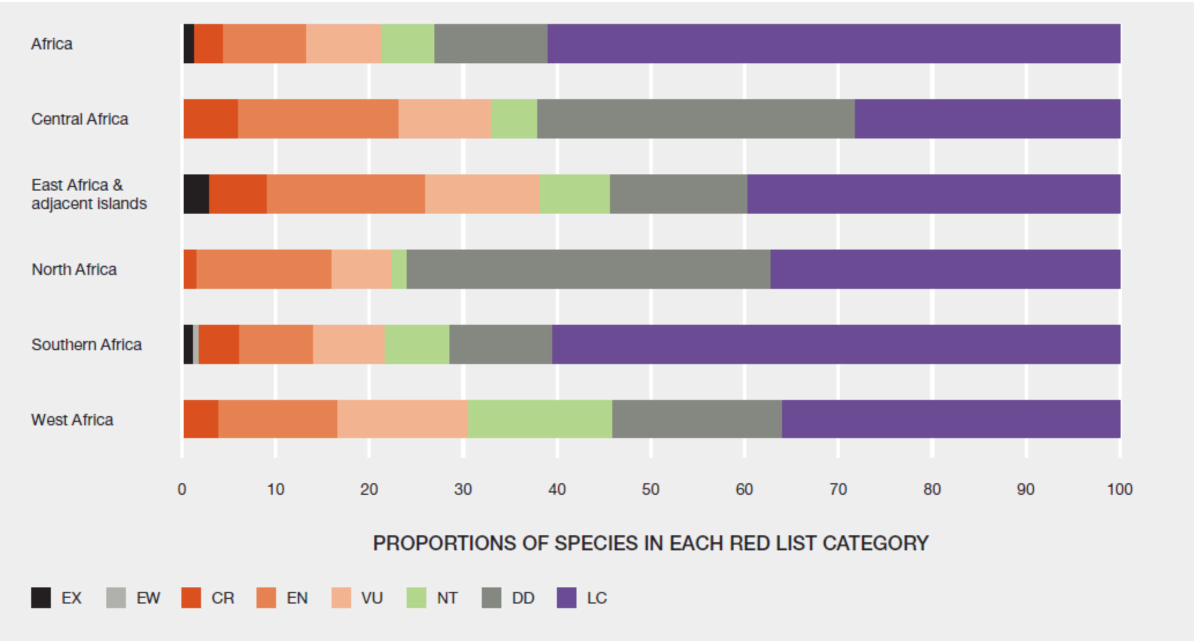


Figure 3.2: Extinction risk of species in the Africa region as a whole and per subregion. Source: Brooks *et al.* (2016a).

Table 3.4: The number of species listed by CITES (on Appendix I, II or III) for birds, mammals, fishes, amphibians and plants (first column) in each of the regions of Africa and the corresponding percentage (second column) of the total for the taxon. Source: https://cites.org/eng/disc/ac_pc.php

Birds										
	Central Africa		East Africa and adjacent islands		North Africa		Southern Africa		West Africa	
	No.	%	No.	%	No.	%	No.	%	No.	%
Appendix I	4	0.6	10	1.51	10	1.51	2	0.3	6	0.91
Appendix II	130	19.49	171	25.23	97	14.5	125	18.73	107	16.01
Appendix III	1	0.15	4	0.6	1	0.15	1	0.15	1	0.15
Total	**134**	**20.24**	**181**	**27.34**	**107**	**16.16**	**127**	**19.18**	**113**	**17.07**
Mammals										
	Central Africa		East Africa and adjacent islands		North Africa		Southern Africa		West Africa	
	No.	%	No.	%	No.	%	No.	%	No.	%
Appendix I	25	4.5	86	15.47	21	3.78	29	5.22	26	4.68
Appendix II	97	16.55	84	14.57	41	6.29	74	12.77	73	12.41
Appendix III	5	0.9	3	0.54	6	1.08	3	0.54	4	0.72
Total	**122**	**21.94**	**170**	**30.58**	**62**	**11.15**	**103**	**18.53**	**99**	**17.81**
Fishes										
	Central Africa		East Africa and adjacent islands		North Africa		Southern Africa		West Africa	
	No.	%	No.	%	No.	%	No.	%	No.	%
Appendix I	2	2.22	4	4.44	5	5.56	5	5.56	3	3.33
Appendix II	9	10	18	20	16	17.78	19	21.11	9	10
Total	**11**	**12.22**	**22**	**24.44**	**21**	**23.33**	**24**	**26.67**	**12**	**13.33**
Amphibians										
	Central Africa		East Africa and adjacent islands		North Africa		Southern Africa		West Africa	
	No.	%	No.	%	No.	%	No.	%	No.	%
Appendix I	1	2.78	16	44.44	0	0	0	0	2	5.56
Appendix II	0	0	17	47.22	0	0	0	0	0	0
Total	**1**	**2.78**	**33**	**91.67**	**0**	**0**	**0**	**0**	**2**	**5.56**
Plants										
	Central Africa		East Africa and adjacent islands		North Africa		Southern Africa		West Africa	
	No.	%	No.	%	No.	%	No.	%	No.	%
Appendix I	7	0.26	45	1.67	1	0.04	56	2.08	1	0.04

Appendix II	254	9.45	1303	48.46	49	1.82	836	31.09	137	5.09
Appendix III	0	0	1	0.04	0	0	0	0	0	0
Total	**261**	**9.71**	**1349**	**50.15**	**50**	**1.86**	**892**	**33.18**	**138**	**5.13**

Africa is the last remaining refuge for megafauna worldwide, however their populations are at risk. Iconic African fauna such as elephants, hippopotamuses and rhinoceroses are currently restricted to a small percentage of their former ranges as a result of the international ivory trade, habitat loss, political instability, and the difficulties of enforcing anti-poaching laws (Figure 3.3). The figure 3.3 shows the range contractions over time for three iconic African herbivores (Ripple *et al.*, 2015). Between 2002 and 2011, forest elephant populations declined by 62%. Elephants are now a missing component from more than 75% of existing structurally intact rainforest in Africa where they once played a potentially important ecological role (Maisels *et al.*, 2013). Losing such megafauna from the second most expansive region of tropical forest in the world may have important consequences on local, regional and macro-scales that go beyond the loss of the species itself.

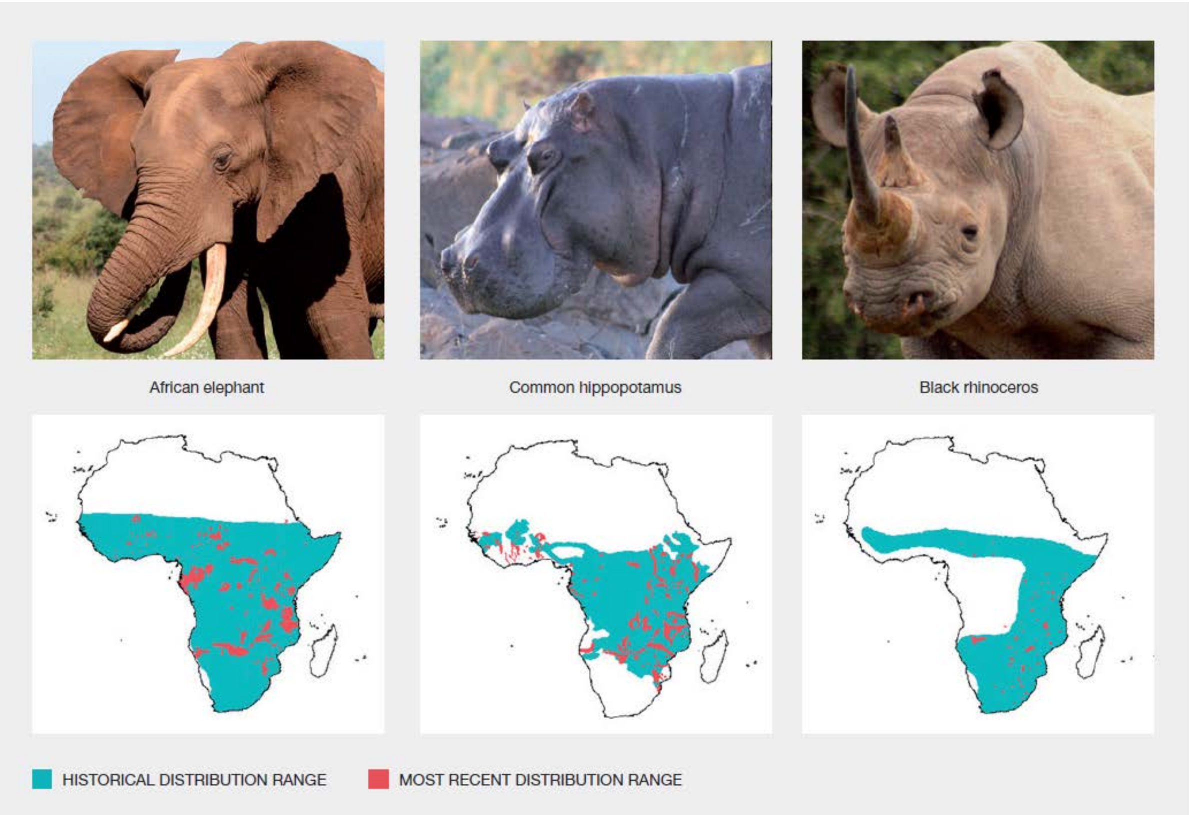


Figure 3.3: Range contractions over time for three iconic African herbivores[3]

3.3.2 Status of ecosystem components

The African region consists of diverse habitats and ecosystems ranging from equatorial rainforests to grasslands to deserts with unique flora and fauna. This region contains nine of the world's 35 biodiversity hotspots (Table 3.3; Figure 3.4) and has three of the world's most biologically diverse

[3]African elephant (circa 1600 versus 2008), common hippopotamus (circa 1959 versus 2008), and black rhinoceros (circa 1700 versus 1987). The historical ranges are in blue, whereas the most recent ranges are represented by darker-colored polygons. For security purposes, the most recent black rhinoceros range polygons (1987) have been moved by random directions and distances. The black rhinoceros range has continued to shrink since 1987 across most of Africa, but has expanded locally in Zambia, South Africa, and Namibia through recent reintroductions, and the most current range polygons are not shown because of the recent poaching pressure on the rhinoceros. Source: Ripple *et al.* (2015).

countries (UNEP, 2008, 2013). These are Madagascar, South Africa and the Democratic Republic of Congo. The Ethiopian Highlands are one of the world's eight major centers of crop diversity (UNEP, 2013). Africa also holds the second largest rainforest (The Congo Basin) in the world after the Amazon. The estimated forest area in Africa was close to 6,750,000 km^2, accounting for about 17% of global forest area and 23% of the total land area of the region (FAO, 2011). Southern Africa's wetlands are among the most diverse, both physically and biologically of any in the world (Taylor *et al.*, 1995).

Figure 3.4: Classification of Africa's relatively stable, vulnerable and critically endangered biological hotspots. Source: UNEP (2013).

A total of 78 priority sites for important plant areas have been identified within the five North Africa countries in this project. In Algeria, 21 important plant areas have been selected within all the major vegetation zones from sea level to 2,300 metres and they are highly floristically diverse. In Morocco, the 19 important plant areas chosen are 2,500 metres above sea level with associated alpine and sub-alpine vegetation, these sites are also exceptionally rich in endemic species for example Toubkal

National Park and Eastern High Atlas Park in the High Atlas mountains. The focus in Tunisia and Egypt has largely been on 13 and 20 important plant areas respectively, and in Libya 5 important plant areas have been selected that represent the coastal belt, mountains and desert region, with a focus on Al Jabal Al Akhdar, the largest important plant area on the Cyrenaican Peninsula which contains 80% of the Libyan flora and is a region of exceptional plant endemism.

3.3.2.1 Protected area status

As the availability of natural resources in non-protected areas dwindles due violation of environmental laws (e.g., illegal hunting), the protected areas are becoming the sole remaining repositories of fuel-wood for local communities in and around protected areas, and forage, etc. (UNEP-WCMC, 2016). Unfortunately, protected areas are now becoming a focus for poaching, illegal grazing, fire and fire suppression, invasion of alien species and other human activities that affect their sustainability (Schulze *et al.*, 2018; Table 3.5; Figure 3.5). It is therefore crucial to improve the management effectiveness of the existing protected areas to better cope with the current level of their erosion. Africa has a number of large transboundary ecosystems, which are areas of land or sea that straddle one or more political boundaries. Some are officially protected areas which are of extreme importance for safeguarding the remarkable animal populations of Africa and their habitats. The importance of transboundary protected areas is especially obvious for migratory species. Examples of transboundary protected areas in Africa include Nyungwe forest (Rwanda)/Kibira National Park (Burundi); Mt Elgon national park (Kenya and Uganda) Great Limpopo Transfrontier Park (Mozambique, South Africa, and Zimbabwe); Tri-National Dja-Odzala-Minkébé network of protected areas in Cameroon, Gabon and DRC, and the W-Arly-Pendjari complex in Benin, Burkina Faso and the Niger.

Table 3.5: The most frequently reported threats in Afrotropical realm (sub-Saharan Africa) and Palearctic realm (including North Africa). Source: Schulze *et al.* (2018).

Realm	Biome group	Number of sites	Most frequently documented threat	2nd most frequently documented threat	3rd most frequently documented threat
Palearctic	Non-tropical forest	479	Recreational activities	Hunting and collecting terrestrial animals	Dams and water management/use
Palearctic	Non-tropical savannahs, shrub-and grasslands	51	Recreational activities	Hunting and collecting terrestrial animals	Livestock Farming and Ranching
Afrotropical	Tropical forests	150	Hunting and collecting terrestrial animals	Gathering	Logging and wood harvesting
Afrotropical	Non-tropical savannas, shrub- and grasslands	22	Invasive non-native/ alien species/ disease	Fire and fire suppression	Recreational activities

Afrotropical	Mangroves	7	Fishing and harvesting aquatic resources	Hunting and collecting terrestrial animals	Gathering terrestrial plants

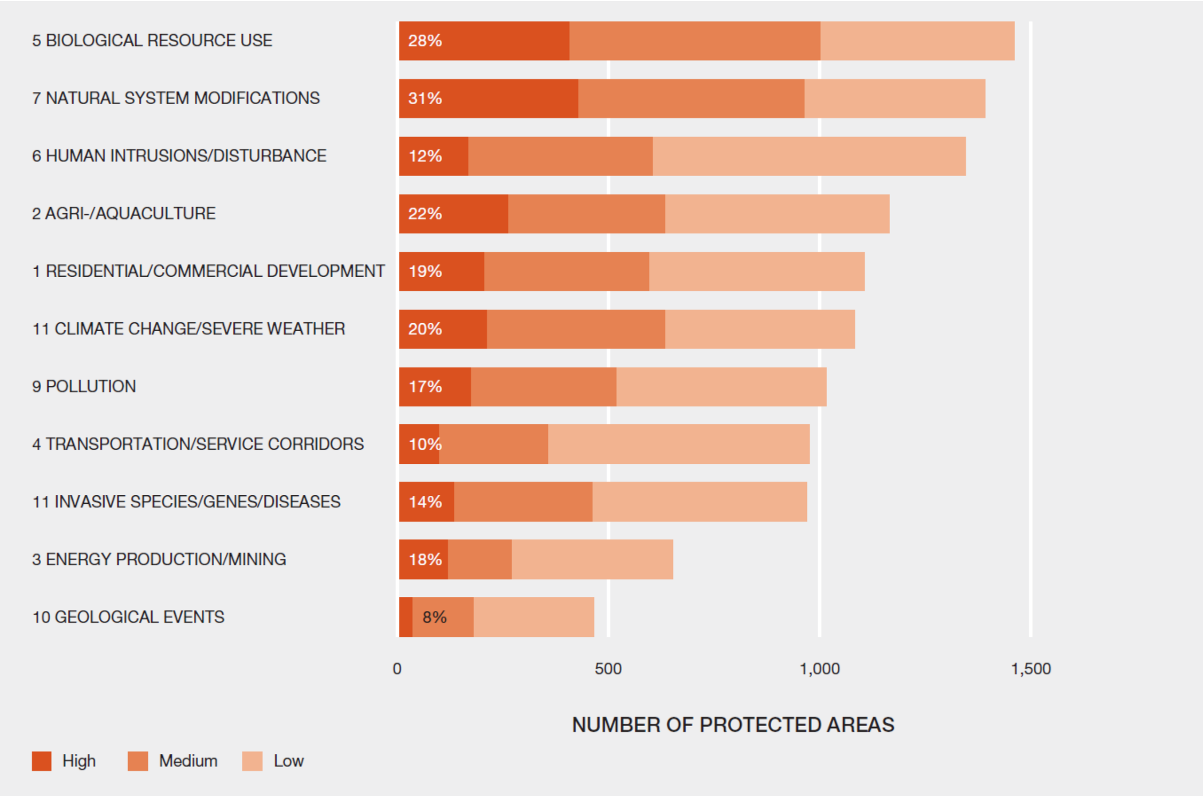


Figure 3.5: Ranked frequency of threats across protected areas. Source: Schulze *et al.* (2018).

3.3.3 Broad temporal trends in biodiversity and ecosystem components

Africa is rapidly losing its biodiversity due to uncontrolled exploitation and fragmentation of natural habitats (UNEP, 2013). Africa's Living Planet Index shows an overall reduction of 39% invertebrate abundances between 1970 and 2008 (WWF, 2012). This is higher than the estimated loss rates globally (30%) but much lower than the 59% loss across the tropics. Loss of biodiversity in Africa is occurring fastest in the species-rich forest zones, including Western and Central Africa and Madagascar (Craigie *et al.*, 2010). Impacts on smaller species, including invertebrates and rodents, are relatively unknown.

Ecosystems in the African regions are also declining rapidly. Over 3 million hectares of natural habitat are converted for other uses each year (COMIFAC, 2011). From 1990 to 2015, Africa has experienced the biggest forest area loss compared to the rest of the world except South America. The rate of forest loss in Africa has decreased substantially in the past five years, and average per capita forest area declined from 0.8 to 0.6 hectare/person (FAO, 2015a). Freshwater ecosystems, which provide the sole habitats for rich, endemic, and sensitive biota, and supply food and water to millions of people in Africa, are currently threatened by dams' constructions, unsustainable harvesting, wetland drainage for agriculture, invasive species and pollution that have resulted in degradation of these ecosystems continent-wide (Strayer *et al.*, 2010).

Studies suggest that climatic changes are already having negative impacts on ecosystems in Africa with altered rainfall patterns and temperature regimes (Chapter 4; section 4.2.2.2). Models predict future changes especially in the drier habitats of Africa including Northeast Africa, the West Sahel, and Southwest Africa (UNEP-WCMC, 2016). Africa's coral reefs in the Indian Ocean experienced massive bleaching in 1998, and again in 2016 as a result of extreme ocean warming events resulting in over 50% reef mortality in some regions (Obura, 2016). Damage to coral reef systems has far-reaching implications for fisheries, food security, tourism and overall marine biodiversity.

3.3.3.1 Protected area trends

In total, Africa contains 8,338 protected areas totaling 4,704,013 km^2 of which 4,358,096 km^2 is terrestrial and 345,917 km^2 marine (UNEP-WCMC *et al*., 2017). Much effort has recently gone into designating new protected areas in Africa with the hope of saving areas of crucial importance for biodiversity conservation (UNEP-WCMC, 2008).

The first Indigenous and Community Conserved Area (ICCA) included Conservancies in Zimbabwe, Namibia, Kenya and South-Africa, and their main benefits for local people were from non-consumptive tourism. Now, there are more and more community-based management areas, included (or not) in the category VI of IUCN, oriented towards sustainable use of natural resources (Aubertin *et al.*, 2011). For instance, in Casamance, Senegal, the ICCA of the Rural Community of Mangagoulack, created in 2004, known as *Kapoye Wafwolale Wata Nanang* (a joola expression meaning 'Our heritage, for us all to preserve') is oriented towards sustainable use of the mangrove forests and rivers to the benefit of the local fishers and directly managed by them(Cormier-Salem, 2014).

Despite these advances in habitat protection, rapid population growth coupled with globalisation and an increasing demand for food, shelter and income over the last century have led to the increased loss of habitat and ecological isolation of protected areas (DeFries *et al.*, 2005). In Africa, this trend has been exacerbated by large-scale land-use changes financed by foreign and local capitals interested in the extraction of natural resources and the production of agricultural crops for international markets (Hilson *et al.*, 2004; Yelpaala *et al.*, 2005; Cotula *et al.*, 2009).

3.3.3.2 Environmental health trends

This theme contributes to the assessment of the risk that diseases cause to human well-being and animal. It encompasses the health of the environment or the ecosystem where humans and animals live in harmony with nature in a balance necessary for human well-being but sensitive to extrinsic influences. It is a symbiotic lifestyle in which each party benefits from the existence of the other. While parasitic cohabitation proves harmful for one of the living beings concerned. Thus, pathogens occur under certain conditions and harm human, animal or plant health. These agents are either of viral, bacteriological or mycotic origin. Climatic and ecological disturbances promote their virulence even though they are harmless in a healthy natural environment.

Man is as sensitive as the animal or vegetal aggressions of those agents that become pathogenic. This is the case for serious human illnesses such as Ebola, HIV, influenza or rabies and in cases of plague, foot-and-mouth disease or catarrhal fever with high economic impact. While the plant suffers from other infections rather caused by parasitic agents that appear under certain climatic conditions (high heat, too much humidity or high density). This is the case of Bayoud disease in olive tree, the caterpillar *Paysandisia archonqui* infects the palm in the Mediterranean (North Africa). The cork oak is attacked every dry season by a parasite that ravages the forests. Eucalyptus is vulnerable to attacks caused by *Phoracantha semipunctata*.

As for fungal diseases caused by fungi whose development is linked to disturbances of aeration or oxygenation of living beings in sites exposed to their aggressions (mildews, ergot of rye or maize) and other pathogens of legumes or arboriculture. The knowledge of these pathologies has evolved considerably since the vaccine against rabies was manufactured by Louis Pasteur or *Penicillin* was discovered by Alexander Fleming in the last century. However, newly emerging pathogens (e.g., Ebola and HIV) are the subject of intense research to find the cure necessary to neutralize their aggression. The repeated frequency of these human epidemics or animal epidemics affect either the vulnerable human populations or their food stocks or impact the rich biodiversity of the continent hindering the food security of the countries (FAO, 2015a; WOAH, 2017). Wildlife suffers from the human awkwardness that invades the remote territories of these animals introducing livestock-borne pathogens. Wild animals unimmunized against these agents contract the disease and develop epizootics that eliminate a large proportion (rabies, foot-and-mouth disease, rinderpest, avian influenza (WOAH, 2015), to name but a few examples) and other agents carried by domestic animals such as anthrax, blue tongue or coryza.

The role of birds and insects in the dissemination of pathogens is crucial in the contamination of constituents of African and even global biodiversity. To mention also the role of bees in the pollination of plants for the welfare of man and nature but these workers of nature are threatened by the man who introduces into his hives dangerous diseases such as the varroosis that threatens bee industry (WOAH, 2017). The loss of a species has no equivalent value in nature and its restoration remains in the realm of the impossible.

3.3.3.3 Urbanisation, agriculture and biodiversity in Africa

There are five major trends in the process of urbanisation that affect biodiversity and ecosystem services. These trends include: fast spatial expansion of urban areas; impacts of urban expansion on quality of ecosystem services; impacts of urban expansion modifies local climate and affects quality of biodiversity; land for urban agriculture; and impacts on biodiversity hotspots; Seto *et al.* (2013). It is projected that world urban population would increase to five billion by 2030 and this rapid change associated with land conversion threatens biodiversity and ecosystem productivity (Seto *et al.*, 2012). The pressure on African biodiversity is not limited to the continuous loss of species and habitat, the escalating human-driven changes, climate change and land-use and land cover change (UNEP-WCMC, 2016).

One fundamental issue is the challenge of invasive and non-native species in African cities. For instance, Gaertner *et al.* (2016) found that introduction of some exotic species Cape Town South Africa grey squirrels (*Sciurus carolinensis*, Least Concern), Himalayan tahrs (*Hemitragus jemlahicus*, Near Threatened) have contaminated urban biodiversity composition. In West Africa, cultivation of Okra in urban and peri-urban is shown to be responsible for introduction of some invasive weed species that harm ecosystem services particularly pollination and pest control (Stenchly *et al.*, 2017). Similarly, the use of industrial wastewater in West African urban areas, intensive cultivation of spinach (*Spinacia oleracea* L.) kills soil-dwelling arthropods. In other words urban agriculture dictates trends of species diversity depletion. Sometimes, the distribution of exotic species goes hand in hand with agriculture intensification and urbanisation. For instance, in Bujumbura, the capital city of Burundi, researchers found that out of the 404 tree species they recorded in the city 57% are native while 43% were introduced (Bigirimana *et al.*, 2011).

Here, it is important to note that although urbanisation threatens biodiversity in Africa and elsewhere, table 3.6 outlines some of the most critical ecological zones in Africa that is likely to be affected by increasing urbanisation. Comparison of changes over time come through projections undertaken in various research laboratories as shown in figure 3.6.

Table 3.6: Biodiversity hotspots and projects threats by urban growth. Source: van Vliet *et al.* (2017).

Biodiversity hotspot	**Hotspot area not threatened by urban expansion (km^2) (% of hotspot)**	**Urban expansion in hotspot (km^2) by probability quartile range (% of hotspot)**				**Urban extent in hotspots *ca.* 2000 (km^2) (% of hotspot)**
		>0–25	>25–50	>50–75	>75–100	
Cape Floristic Region	80 400 (97)	175 (0.2)	25 (0.0)	0 (0.0)	1,100 (1.3)	875 (1)
Coastal Forests of Eastern Africa	287 575 (95)	9775 (3)	275 (0.1)	300 (0.1)	5350 (2)	800 (0.3)
Eastern Afromontane	902 950 (86)	99 775 (10)	8400 (1)	6500 (0.6)	28 400 (3)	1500 (0.1)
Guinean Forests of West Africa	482 775 (75)	101 950 (16)	5800 (1)	3775 (0.6)	43 675 (7)	4725 (1)
Horn of Africa	1,597,450 (96)	57 275 (3)	2650 (0.2)	4650 (0.3)	5300 (0.3)	1575 (0.1)
Madagascar and the Indian Ocean Islands	590 525 (99)	6050 (1)	350 (0.1)	75 (0.0)	2100 (0.4)	275 (0.0)
Maputaland-Pondoland-Albany	260 125 (94)	6300 (2)	1375 (1)	1475 (0.5)	7225 (3)	1075 (0.4)
Mediterranean Basin	1 687 550 (80)	302 825 (14)	23 750 (1)	16 650 (1)	54 675 (3)	33 450 (2)
All hotspots	21 666 625 (91)	1 325 225 (6)	100 750 (0.4)	77 200 (0.3)	436 175 (2)	203 900 (1)

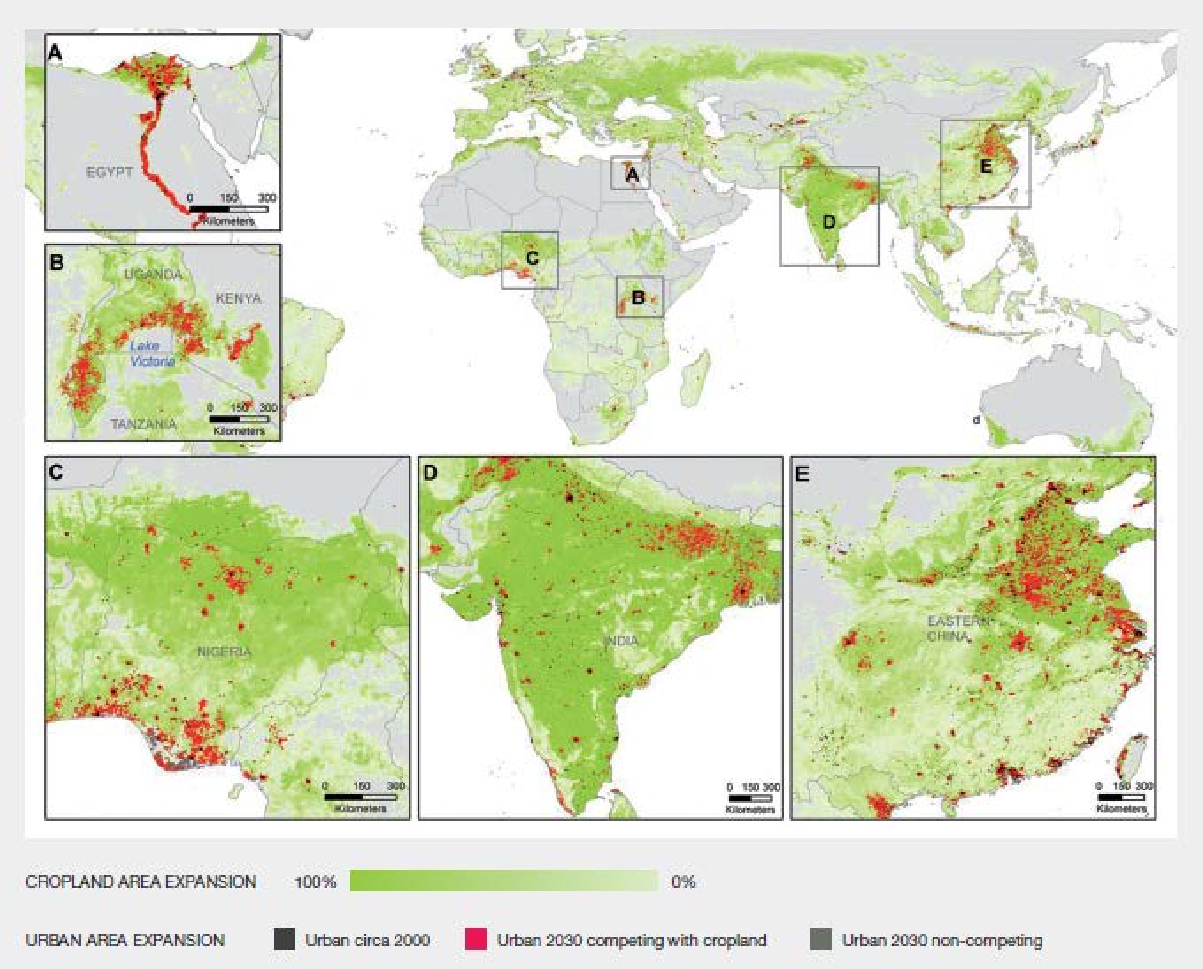


Figure 3.6: Projected urban land expansion and its implications for croplands in Africa. Source: d'Amour *et al.* (2016).

3.4. Subregional analysis

3.4.1. North Africa

3.4.1.1. Terrestrial

3.4.1.1.1. Mediterranean Forest

Status: The Mediterranean woodland and forest ecoregion of North Africa stretches from the coastal plains to the hills of northern Morocco, Algeria and Tunisia, and eventually surrounds the Atlas Mountains; it extends approximately 358,936 km^2 (Olson *et al.*, 2001). Key protected areas include El Feija National Park, Châambi, Boukornine, Ichkeul, Bouhedma, Jebel Serj National Parks in Tunisia, Chrea, Djurdjura, Tlemcen, Theniet El-Had, Gouraya, Taza, El Kala, Belzma National Parks and biosphere reserve in Algeria, and Talassemtane, Al Hoceima, Tazekka, Ifrane , Khenifra, Eastern High Atlas, Toubkal, Souss Massa and Khenifiss National Parks in Morocco. The Biosphere Reserves are represented in Morocco by *Argania spinosa*, Southern Oasis Morocco, Cedar Biosphere Reserve and Intercontinental Biosphere Reserve of the Mediterranean between Morocco and Andalusia (Spain); in Algeria by Tassili N'Ajerr, El-Kala, Djurdjura, Chrea, Gouraya, Taza Biosphere Reserves; in Tunisia by Ichkeul, Djebel Bou-Hedma, Zembra and Zembretta, Djebel Chambi Biosphere Reserves; in Egypt by Wadi Allaqui and Omayed Biosphere Reserves; in Sudan by Dinder and Radom Biosphere Reserves and the Transboundary Biosphere Reserve of the Senegal River Delta between Mauritania and Senegal.

Morocco holds the greatest amount of protected Mediterranean forest in North Africa. The Mediterranean Basin is the third richest biodiversity hotspot in the world (Mittermeier *et al.*, 2004). However, recent biodiversity studies in the North African region are limited.

The Mediterranean forests of Morocco and Algeria are two centres of high plant diversity with a high degree of endemism and rarity (Figures 3.7 & 3.8) because of their position at the crossroads of two continents, and transitions between tropical and temperate climates (Médail *et al.*, 1999). They hold several types of forest represented by fir, cedar, argan tree, atlas cypress, xeric pine, Berber thuya, cork oak, holm and holly oak, red juniper, thuriferous juniper and carob species. There are approximately 70 species of mammals in this region and some species are endemic, including some charismatic taxa such as Barbary leopards (*Panthera pardus panther*, Critically Endangered), Monk seal (*Monachus monachus*, Endangered), and Barbary macaque (*Macaca sylvana*, Endangered) and birds such as the Waldrap Ibis (*Geronticus eremita*, Endangered), the only world wild colony in Morocco (Butynski *et al.*, 2008; Karamanlidis *et al.*, 2015; BirdLife International, 2016; Stein *et al.*, 2016).

The flora and fauna diversity of Mediterranean forest habitats are highly threatened and highly endemic and need urgent research and implementation of the legislation for protection. The forests provide a rich source of products that provide sustenance and income for communities living in and around the forest (M'Hirit, 1999), however, recent human encroachment and overuse of resources are currently threatening these rich primary forests considered as national heritage (M'Hirit, 1999).

The original forest cover of this ecoregion has been dramatically reduced for agricultural and pastureland (Zaimeche, 1994). In Algeria, only 1,000 km^2 of the original 10,000 km^2 of wild-olive and carob forests remain, and only 6,800 km^2 of the original 18,000 km^2 of holm oak forest remains. In Morocco, 5,000 km^2 of the estimated 36,240 km^2 original wild-olive and carob forests remain, and 14,320 km^2 of the original 24,500 km^2 holm oak forest remains. The original extent of the cork oak forests in North Africa is estimated to be 30,000 km^2, (3,500 km^2 in Morocco, 4,500 km^2 in Algeria, and 455 km^2 in Tunisia). Removals of wood and non-wood forest products for economic purposes also threaten this ecosystem; for example, firewood collection dominates 80–100% of total wood forest

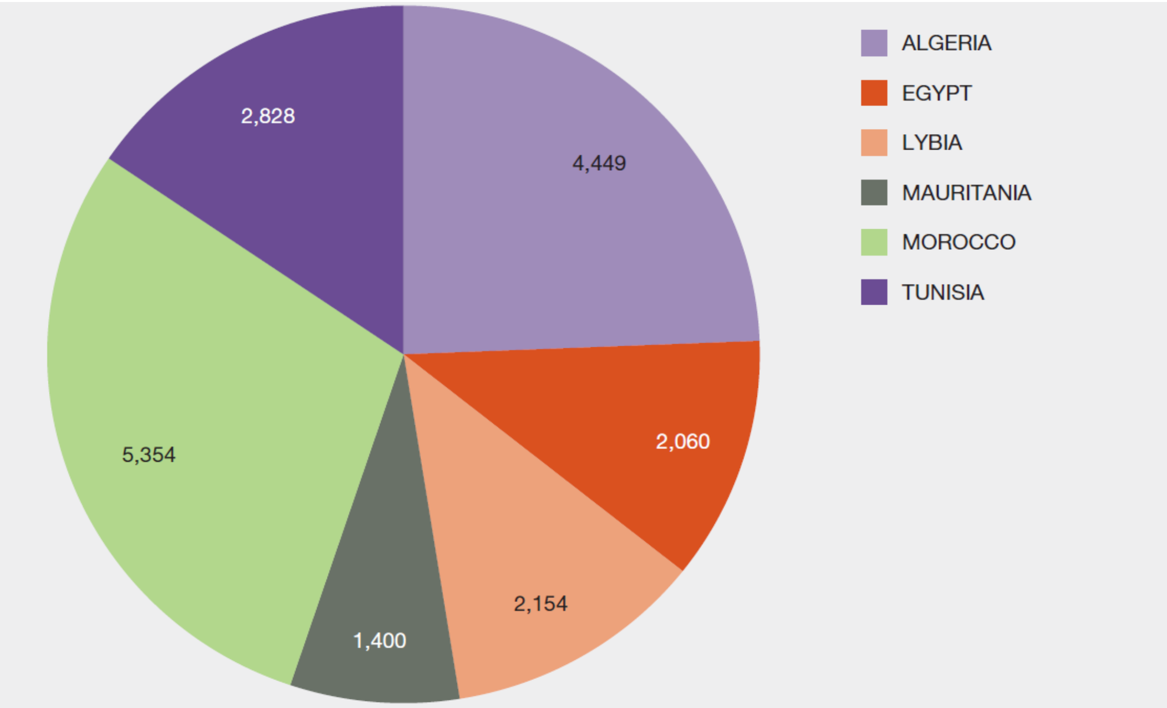


Figure 3.7: Number of vascular plants in the countries of North Africa. Source: El Oualidi *et al.* *(*2012).

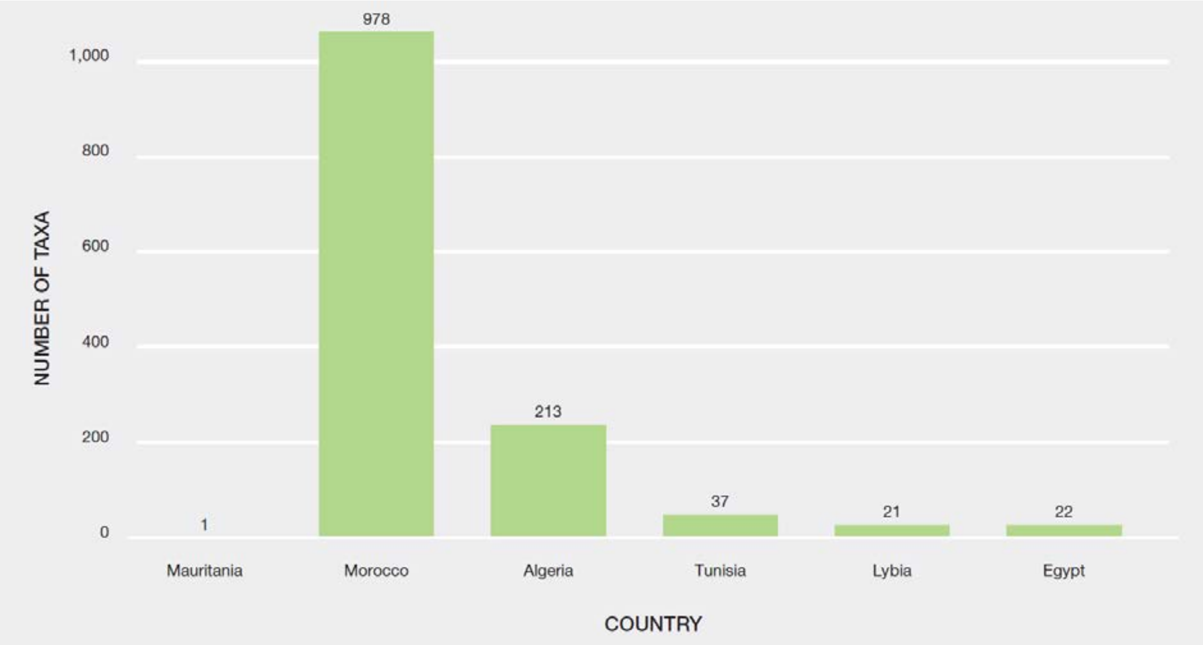


Figure 3.8: Endemic vascular flora in North Africa. Source: Dobignard *et al.* (2013).

product removals in Tunisia, Morocco and Lebanon (Croitoru, 2007). Net carbon losses in these three countries vary within 0.08–0.53 tons of Carbon/hectare/year (Croitoru, 2007).

The protected areas in this ecoregion are generally lacking in management plans and those that do have management plans lack resources to implement them. Recent biodiversity studies in this habitat are limited and there is an urgent need for research to better understand the current conservation status and trends affecting the Mediterranean forests, including biodiversity and ecosystem services, in this region (Médail *et al.*, 1999).

3.4.1.1.2. High mountain habitats

Status: North Africa's mountain ranges include the Atlas and Rif mountains, and their highest peaks include Morocco's Jbel Toubkal (4,167 metres) and Ighil M'Goun (4,071 metres). Mediterranean conifer and mixed forests grow in high elevations of the major mountain massifs, and small, isolated relict stands of fir and pine forests are endemic (Olson *et al.*, 2001). The mountain regions' high endemism includes 91 endemic plant species in the Tell Atlas Mountains, at least 190 in the Rif Mountains, and 237 endemic species in the Middle Atlas Mountain range (FAO, 2015a). Flagship species include the argan tree (Sapotaceae) and the endangered Mediterranean fir (*Abies marocana*) (Alaoui *et al.*, 2011; Table 3.7). One of the few known remaining habitats of the striped hyena (*Hyaena hyaena*, Near Threatened) is found in the Djurdjura Mountains (Arumugam *et al.*, 2008). Only 1% of mountain areas are found within protected areas.

The region's mountains have an average human density of 15 people/km^2 (Pfeifer *et al.*, 2012), representing a 2% increase since 2000. Humans' greatest service from the region's mountain ecosystems is their 'water tower' function. Although dominated by desert, the tallest peaks hold snow for weeks to months and meltwater contributes to and regulates water flow that benefits agriculture from late winter to early summer (UNEP, 2014). Snowmelt from the High Atlas Mountains contributes approximately 25% of streamflow in its catchments (Boudhar *et al.*, 2009), and the region supplies the headwaters for the Sebou River, the Oum Errabiaa and Oued Moulouiya. The region's mountain ecosystems also provide grazing and tourism (trekking and skiing), and hold important sacred sites such as Egypt's Mount Sinai (UNEP, 2014) and Zaouia in Atlas mountain.

Trends: Historical pressures to the region's mountain ecosystems include habitat transformation for agriculture, which has increased markedly between 1984 and 2013, especially around the Oued N'Fis (UNEP, 2014). Wastewater pollution generated by growing urban areas is compromising river water quality (Perrin *et al.*, 2014). Atlas cedar forests found among the Aures Mountains and the Djurdjura Mountains are under pressure from climate change, fire and pastoralism, though wood harvest rates are low (Djema *et al.*, 2009). The Rif Mountains are exceptionally vulnerable to soil erosion, losing an average of 10 m^3/hectare/year (Croitoru *et al.*, 2005). Forest cover, although limited, has increased by 6% overall and by 78% within national parks (2000–2009) (Pfeifer *et al.*, 2012). The region holds some of the Mediterranean basin's highest proportions of threatened terrestrial amphibians, mammals, dragonflies and reptiles (Cuttelod *et al.*, 2008).

Future dynamics: Climate change poses the most serious threat to North Africa's mountain ecosystems in the future. Predicted temperatures increase, precipitation declines and longer dry season (Pfeifer *et al.*, 2012) will lead to declines in snow and hence in 'water tower' function. Resulting water shortages are projected to decrease agriculture by 8% by the end of the 21st century (Montanari, 2013).

Table 3.7: List of main terrestrial forest ecosystems in North Africa.

Main Forest Ecosystems	**Area (hectares) in Morocco(1)**	**Area (hectares) in Algeria(2)**	**Area (hectares) in Tunisia(3)**
Quercus rotundifolia Lam.	1,415,201	354,000	83,000
Cedrus atlantica (Endl.) Carrière	133,653	23,000	Absent
Argania spinosa L.	871,210		Absent
Quercus suber L.	377,482	480,000	100,000
Quercus coccifera	+	+	+
Juniperus phoenicia, *Juniperus thurifera*	244,837	227,000 (*Juniperus phoenicea*)	+
Reforested	490,518		?
Other	102,207		
Tatraclinis articulata (Vahl) Masters)	565,798	191,000	22,000
Pinus sp.	82,115	804,000	?
Pin d'Alep (*Pinus halepensis* Miller)			297,000

Pinus pinaster Aiton	+	+	?
Quercus faginea Lam.	9,091	65,000 (*Quercus afares*)	6,414
Abies maroccana Trabut	3,174	Absent	Absent
Acacia raddiana Savi	1,000,000	+	+
Acacia ehrenbergiana Hayne	+	+	+
Ceratonia siliqua L.	+	+	+
Other	5,764	143,000	
Total	**5,301,050**	**3,050,000**	
Stipa tenacissima L.	3,000,000	3,037,000	+
Total forest area	5,719,000 (without alfa grass)	1,492,000	1,056,000

+: present
(1) Morocco (Source: Le grand livre de la forêt marocaine. Editions Mardaga, 1999)
(2) Forêt méditerranéenne t. XV, n° 1, janvier 1994
(3)République Tunisienne, Ministère de l'Environnement et du Développement Durable, Agence Nationale de Protection de l'Environnement. Guide forêts durables. 2005

In Libya, forest ecosystems cover 217,000 hectares and are found in the area of Jabal Al Akhdar in the north-east, comprising the following: moist forest, with *Quercus calliprinos, Laurus nobilis, Arbutus pavarii* (Vulnerable)*, Olea europaea, Ceratonia siliqua* (Least Concern)*, Quercus coccifera* (Lower Risk/near threatened)*, Cupressus sempervirens* (Least Concern)*;* secondary moist forest, with *Juniper phoenicea*, *Pinus halepensis* (Least Concern), *Olea europaea, Arbutus pavarii* (Vulnerable)*;* forests in semi-arid regions, with *Sarcopoterrium spinosium*, *Pinus halepensis* (Least Concern), *Juniper phoenicae, Pistacia lentiscus* (Least Concern)*, Rhus tripartitum, Periploca laevigata;* and forests to the south of Jabal Al Akhdar, with *Rhus tripartitum*, *Pistacia lentiscus* (Least Concern), *Periploca laevigata*. In Egypt, forest ecosystems cover 67,000 hectares. The main natural ecosystems are organised by *Acacia raddiana, Balanites aegyptiaca*, *Tamarix sp*., and *Salvadora persica*. In Sudan, the main forest ecosystems are represented by *Acacia raddiana* Savi, *Acacia mellifora* (M. Vahl) Benth, *Balanites aegyptiaca* Delile and *Boscia senegalensis* Poiret in Lam. In Mauritania the forest ecosystems cover 267,000 hectares. The main natural ecosystems are organised by *Acacia raddiana*, *Acacia ehrenbergiana* (Least Concern), *Acacia nilotica* (Least Concern), *Balanites aegyptiaca*, *Leptadenia pyrotechnica*, *Boscia senegalensis* and *Euphorbia balsamifera*.

3.4.1.1.3. Savannah and grassland

Status: Savannah and grasslands in North Africa are located in arid and Saharan areas (Savannah) and in High mountain areas (grasslands). The Siwa protected areas (Northwest Egypt, near Libya border) include 53 plant species, 28 wild mammals including 7 rare species threatened with extinction (namely cheetah, Striped hyena, Egyptian gazelle, white gazelle, red fox, wild cat and Fennec fox), 32 reptile species, 164 bird species and 36 insects and number of other invertebrates areas (Taleb *et al*., 2013). In Wadi El Gemal and Hamata (Egypt), 140 plant species, including 32 used in traditional medicine, 24 mammal species, 29 species of reptiles and amphibians and 45 bird species were recorded areas (Taleb *et al.*, 2013).

Grassland ecosystems are common in Morocco especially in High Atlas and Middle Atlas areas (Taleb *et al.*, 2013). They are herbaceous and based on hemicryptophytes, geophytes, mesophiles and hygrophile associations of important forage value (Ouhammou, 2013). Their existence is conditioned by water availability (Ionesco *et al.*, 1962). These grasslands are floristically rich, with many rare, threatened and/or endemic flora. They are characterised by species such as *Agropyrum festucoides*, *Poa alpina*, *Lolium perenne*, *Holcus lanaus*, *Ranunculus acris* (Least Concern), *Trifolium repens*, *Campanula mairei* (Vulnerable), *Rorippa atlantica*, *Rumex pulcher*, *Eryngium variifolium* (Vulnerable) and *Aconitum lycoctonum*. Various types of grasslands can be distinguished according to altitude. In the High Atlas, Ouhammou (2013) distinguished four grassland types: Grassland with *Lolium perenne*, *Holcus lanatus*, *Inula viscosa*, *Ranunculus acris* (Least Concern), and *Trifolium repens*; localised between 1,300 and 2,300 metres. Grassland with *Eryngium variifolium* (Vulnerable), *Alchemilla arvensis* and *Rumex pulcher*, found in wet places. Grassland with *Cirsium chrysacanthum* (Near Threatened), *Campanula mairei* (Vulnerable) and *Rorippa atlantica*; extends up to the high mountains.

<u>Trends and future dynamics:</u> The subregion is vulnerable to desertification and drought. *Argania spinosa, Arbutus pavari, Cedrus atlantica* (Endangered)*, Abies pinsapo var. marocana, Euphorbia echinus, Euphorbia resinifera, Senecio antieuphorbium, Thymus algeriensis,* and *Thymus broussonettii* are endangered. In Sudan populations of the red-fronted gazelle, Dama gazelle, Barbary sheep, Nubian ibex and lion have declined to critical levels and number of threatened species is increasing. Dorcas, which was considered the most abundant species in Sudan, is threatened by habitat fragmentation and poaching. The 2017 IUCN Red List Animals listed Dorcas gazelle as Endangered in Morocco and Libya, Algeria as Probably Vulnerable, Tunisia and Egypt as Vulnerable and Sudan as Probably Near Threatened or Vulnerable. The 2017 IUCN Red List Animals listed Scimitar-horned Oryx (*Oryx dammah*) as Critical, Extinct in Algeria, Egypt, Libya, Mauritania, Senegal, and South Western Sahara of Morocco, and probably extinct in Sudan and Tunisia. The 2017 IUCN Red List Species listed the Scimitar-horned Oryx as Extinct in the wild. It now survives only in zoos and in protected area, as Sous Massa National Park in Morocco. The 2017 IUCN Red List Animals listed the Addax (*Addax nasomaculatus*) as Critically Endangered.

Small gazelles have also declined drastically in the Sahara. The Slender-horned Gazelle or Rhim (*Gazella leptoceros*), native to North Africa, is now extinct in Western Sahara, and endangered throughout its range, according to the 2000 IUCN Red List Species. The endangered Dama Gazelle (*Nanger dama*), also a heavily hunted species, is extinct in Algeria, Libya, Mauritania and Morocco. Cuvier's gazelle (*Gazella cuvieri*) is endemic to mountains and hills of the Atlas and neighbouring ranges of north-west Africa. According to the Red List/IUCN (2016), the species survives in endangered populations in Algeria, Morocco and Tunisia.

3.4.1.1.4. Dryland and desert

<u>Status:</u> The desert comprises much of North Africa, excluding the fertile region on the Mediterranean Sea coast, the Atlas Mountains of the Maghreb, and the Nile Valley in Egypt and Sudan. The Sahara desert covers large parts of: Algeria, Egypt, Libya, Morocco, Sudan and Tunisia. The flora of the Sahara desert in North Africa is relatively poor but very remarkable, composed mainly of *Phoenix dactylifera* (Least Concern), *Acacia raddiana, Acacia ehrembergiana, Balanites aegyptiaca, Retama retam,*

Genista saharae, Gymnocarpos decander, Convolvulus trabutianus, Foleyola billotii, Zilla macroptera, Spergularia tomentosa, Fredolia aretioides, Traganum nudatum, Boscia senegalensis, Maerua crassifolia, Anastatica hierochuntica. Several species of fox live in the Sahara desert including: the fennec fox, pale fox and Rüppell's fox. The Addax, a large white antelope, can go nearly a year in the desert without drinking. The Dorcas gazelle is a North African gazelle that can also go for a long time without water. Other notable gazelles include the Rhim gazelle and Dama gazelle. The Saharan cheetah (northwest African cheetah) lives in Algeria. There remain not more than 250 mature cheetahs in Sahara desert. The other cheetah subspecies (northeast African cheetah) lives in Sudan. There are approximately 2,000 mature individuals left in the wild (Belbachir, 2008; BBC News, 2009). Other animals include the monitor lizards, hyrax, sand vipers, and small populations of African wild dog (Borrell, 2009; Woodroffe *et al.*, 2012) and red-necked ostrich. Other animals exist in the Sahara (birds in particular) such as African Silver bill and black-faced fire finch, among others. Dromedary camels and goats are the domesticated animals most commonly found in the Sahara.

Two-thirds of the area of Sudan is arid or in semi-desert zone and desert ecosystem capers almost 35% of the country. The historical distribution of temporary presence of the movements of the Scimitar-horned Oryx includes all of Saharan and sub-Saharan North Africa between the Atlantic and the Nile. From the 1950’s data Scimitar-horned Oryx is probably now extinct in Sudan (Wilson, 1980). The last precise data are of groups of up to 50 individuals in the Wadi Howar region and on the temporary gizu pastures north of the Wadi Howar in 1964 (Lamprey, 1975), and the capture of an individual at the westernmost part of the Sudanian Wadi Howar in 1973 (Lamprey, 1975). Newby (1982, 1988) estimates that extinction of Scimitar-horned Oryx took place in the 1970’s. Dorcas gazelle occupies two allopatric habitats (i.e., west and east of the Nile). In Morocco, Oryx was documented in the regions south of the Oued Drâa (Loggers *et al.*, 1992) and perhaps in Oued Noun (Joleaud, 1918). The Scimitar-horned Oryx was reintroduced in Morocco within large enclosures (Reserved’Arrouais: about 1000 hectares) in Souss Massa National Park.

In Egypt’s dry and sub-humid habitats cover over 90% of the territory, combining different ecosystems (Table 3.8). The Egyptian desert was home to 6 species of antelopes until the mid-1940s: Mountain gazelle (*Gazella gazella*, Vulnerable), Dorcas Gazelle (*Gazelle dorcas*, Vulnerable), Scimitar Horned Oryx (*Oryx dammah*, Extinct in the Wild), Rhim Gazelle (*Gazella leptoceros*, Endangered), Addax (*Addax nasomaculatus*, Critically Endangered) and African Wild Ass (*Equus asinus*). As a result of hunting activities and drought, the Mountain Gazelle, Scimitar Horned Oryx, Addax and African Wild Ass have disappeared completely. Only the Dorcas Gazelle (*Gazelle dorcas*, Vulnerable) and Rhim Gazelle (*Gazelle leptoceros*) are still present today.

<u>Trends:</u> Northeast African cheetah is currently extinct in the wild in Egypt and Libya. In Egypt, the El Omayed deserts protectorate, includes 251 plant species (1 Endemic, 11 Threatened, 17 Endangered with Extinction) and 324 animal species including 39 bird species (4 Endemic, 1 Globally Endangered, 19 Rare); 10 mammals (1 Endemic, 2 Endangered with Extinction, 4 Rare); 33 reptiles (3 Endangered with Extinction, 12 Under environmental threats); and 242 insect species (2 Endangered with Extinction). In the Wadi Allaqi protected area, biodiversity is represented by 139 plant species (98 of them became extinct between 2000 and 2006 and 6 species are threatened due to over and random grazing). The Dorcas Gazelle (*Gazelle dorcas*) and Rhim Gazelle (*Gazelle leptoceros,* Vulnerable) are threatened with extinction.

Table 3.8: Types and status of main ecosystems in North Africa. Source: Radford *et al*. (2011)

Type of Ecosystem	**Current state**	**Evolution of habitat (past 20 years)**	**Future trend**	**Nature of ecosystem services for the population**	**Impact on the population**	**Threats (various)**
Forests and shrublands	Very clear, in continued deterioration	No reference state but the continuing deterioration in response to increasing pressure	Degradation of forests and shrublands, loss of biodiversity, depletion of species etc.	Firewood, construction and carpentry wood, harvesting of mushrooms, lichens, medicinal plants, paths etc.	Reduction of pastoral resources and the number of livestock, increased poverty, rural exodus etc.	Fuelwood harvesting, construction and woodworking, harvesting mushrooms, medicinal plants, grazing etc.
Steppes tree	Very marked deterioration	No reference state but the continuing deterioration in response to increased pressure	Tendency to purely steppe formations from degradation	Firewood, construction and carpentry wood, medicinal plants, paths etc.	Decline in resources for livestock, rural exodus, poverty	Pasture, expansion of agricultural land
Steppes of high mountains	Enough conserved	No great change	Increasing human pressure leading to resource degradation in forests and shrublands	Firewood, background, harvesting of medicinal plants.	No significant negative impact	Grazing, firewood, expansion of agricultural land
Stipa tenacissima steppes	Enough conserved	No great change	Loss of biodiversity	Mainly grazing	No significant negative impact	Grazing, hunting
Meadows and lawns	Too grazed	Regressing	Regression in terms of	Grazing	Reduction of pastoral resources	Grazing

Type of Ecosystem	Current state	Evolution of habitat (past 20 years)	Future trend	Nature of ecosystem services for the population	Impact on the populatio n	Threats (various)
Pasture			area and biodiversity			
Wetlands	Regressing in terms of area and biodiversity	Regressing	Regression in terms of area and biodiversity	Grazing, fishing, and drinking	Losses of some ecosystem services for local people	Draining, pollution, agriculture, overfishing in control, tourism
Grasslands	Regressing in terms of area and biodiversity	Dysfunction and regression	Ecosystems dysfunction , degraded habitats, loss of biodiversity , poverty, etc.	Grazing, harvesting of wood, agricultural land extension, urbanisation , climate change	Poverty, diseases, rural exodus, etc.	Grazing, poverty, diseases, rural exodus, expansion of agricultural land, plants harvesting, in control tourism etc.
Drylands and desert	Regressing in terms of area and biodiversity	Dysfunction and regression	Ecosystems dysfunction , degraded habitats, loss of biodiversity , etc.	Grazing, harvesting of wood, agricultural land	Poverty, diseases, rural exodus, etc.	Grazing, expansion of agricultural land, plants harvesting, tourism, poverty, diseases, rural exodus.
Mountains	Regressing in terms of area and biodiversity	Dysfunction and regression	Ecosystems dysfunction , degraded habitats, loss of biodiversity , etc.	Grazing, harvesting of wood, agricultural land extension, urbanisation , climate change	Poverty, diseases, rural exodus, etc.	Grazing, fuelwood, expansion of agricultural land, plants harvesting, tourism, poverty, diseases,

Type of Ecosystem	Current state	Evolution of habitat (past 20 years)	Future trend	Nature of ecosystem services for the population	Impact on the populatio n	Threats (various)
						rural exodus, erosion etc.

3.4.1.1.5. Cultivated lands

Status and trends*:* A total of 5,780 crop plants and their Crop Wild Relative (CWR) taxa found in cultivated fields in North Africa have been recorded (Lala *et al.*, 2017). About 9% (502) CWR taxa is identified as a priority for conservation based on their (i) economic value, (ii) the degree of relatedness of wild relatives to their crop, (iii) threat status using IUCN red list assessment, and (iv) the centre of origin and / or diversity of the crop. Those assessed as threatened using IUCN Red list and national assessment represent approximately 2% (119 taxa) of the CWR in the region. However, 21 taxa are assessed as Critically Endangered, 53 as Endangered, and 45 as Vulnerable (Figure 3.9; Lala *et al.*, 2017).

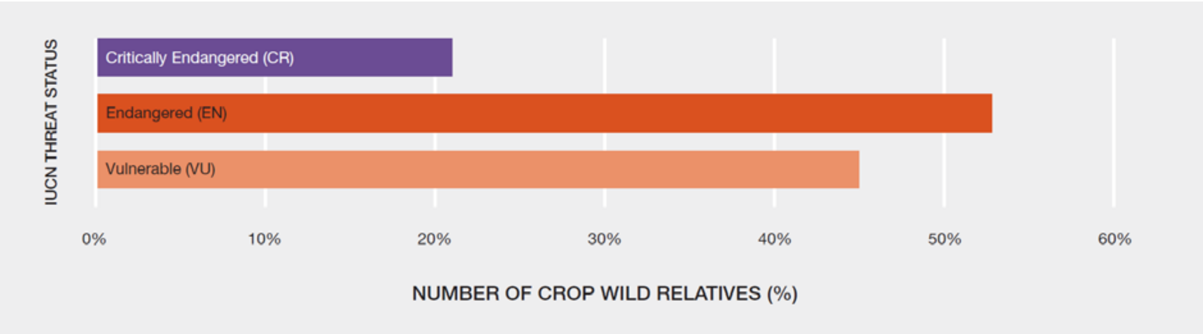


Figure 3.9: Threat status of Crop Wild Relative in North Africa. Source: Lala *et al.* (2017).

The main characteristics of major farming systems in North Africa is the dominance of dryland mixed farming system which contains an agricultural population of 13 million people with 17 million hectares of cultivated land (FAO, 2001a). Other farming systems found in North Africa include irrigated, highland mixed farming and rain-fed mixed farming systems (FAO, 2001a). The prevalence of poverty within the mentioned farming systems ranges from moderate to high (FAO. 2007b).

Future dynamics: Human population in 2050 for Egypt in particular is estimated to be 142 million (Awad *et al.*, 2005). Rapid population growth could continue to be an important impediment to achieving improvements in food security in North Africa. Apart for growth in human population, future disease trends and climate change have substantial effects on North Africa livestock sector, either through impacting the distribution of disease vectors and water availability (Thornton, 2010). This has obvious implications for policymakers and the sheep and cattle industries and raises the need for improved diagnosis and early detection of livestock parasitic disease, along with greatly increased awareness and preparedness to deal with disease patterns that are manifestly changing.

3.4.1.2. Aquatic (Freshwater, Marine and Coastal)

3.4.1.2.1. Wetlands

Status and trends: North Africa is characterized by poor freshwater resources, but there is a good representation of aquatic and wetland habitats along the coast (Figure 3.10). However, these ecosystems are threatened due to anthropogenic activities. For example, the Moroccan and Tunisian wetlands are highly impacted by farming and direct human use that has increased in the past two decades (Birks *et al.*, 2001). Lagoon Mariut in North Egypt is also currently polluted with sewage, industrial waste and agricultural runoff (Adb El-Hady, 2014). Mangroves in North Africa are marginal ecosystems, but remarkable because of the extreme natural conditions, very dry and hot. Only a few groves of mangroves forests are found in the south of Mauritania, in the Senegal Delta and in Sudan. The major species is *Avicennia germinans* (Least Concern) which has remarkable vitality according to its biogeographical limit (Dahdouh-Guebas *et al.*, 2001). Mangrove lagoons and channels are occupied by numerous fish species including many commercially important species (e.g., *Acanthopagrusberda, Chanoschanos*, *Crenidenscrenidens*, and some mugilid species). Sudan boasts a significant number of diverse and relatively pristine wetlands that support a wide range of plants and animals and provide extensive ecosystem services to the local populations. The principal wetlands are the Sudd, which is a source of livelihood for hundreds of pastoralists and fishermen, Dinder, the Machar marshes, Lake Abiad and coastal mangroves. In addition, there are large numbers of smaller and seasonal wetlands that host livestock in the dry season and are important for migrating birds. The rivers and wetlands in Sudan support significant amount of inland fishes which are exploited for sustenance as well as commercial purposes.

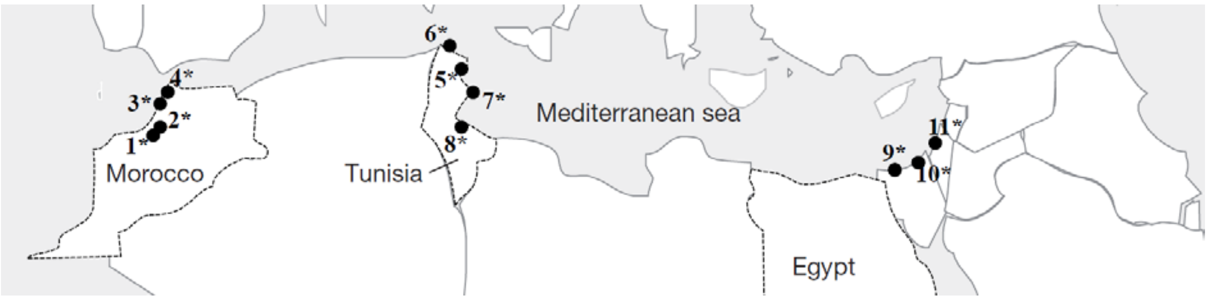


Figure 3.10: The distribution of the wetland lake sites across North Africa selected for the CASSARINA Project. Nine (∗) of these twelve initial sites were used for monitoring and palaeolimnological investigations: 1, Merja Sidi Bou Rhaba∗; 2, Merja Bokka∗; 3,Merja Zerga∗; 4,Merja Khala; 5, Garaet El Ichkeul∗; 6, Megene Chitane∗; 7, Lac de Korba∗; 8, Sebkha Kelbia; 9, Edku Lake∗; 10, Burullus Lake∗; 11, Manzala Lake∗; 12, Qarun Lake. Source: Flower (2001).

3.4.1.2.2. Inland surface waters and water bodies/freshwater

Status and trends: Assessment of the status and distribution of northern African freshwater biodiversity to evaluate the quality of northern African basins was based on five freshwater taxa: fish, molluscs, dragonflies, crabs and aquatic plants representing a range of trophic levels within the food webs that support wetlands (García *et al.*, 2010). Among 877 species and subspecies of freshwater biodiversity that have been evaluated, 247 are categorised as Threatened with Extinction, out of which 61 are Critically Endangered, 72 are Endangered and 114 are Vulnerable (García *et al.*, 2010).

Habitat loss, degradation induced by human activities and pollution are the most important threats. In addition, natural disasters (inundation, earthquake etc.) are severely affecting freshwater species and have a direct impact on populations. These threats are expected to worsen in the future due to the impacts of climate. Therefore, these freshwater basins must be monitored for the assessment for their ecological status based on ecosystem criteria (Biotic indices) in order to avoid loss of this ecosystem and its services (Chapter 6).

Total natural renewable water resources in Sudan are estimated to be 149 km^3/year, of which 20% is produced internally from rainfall and 80% flows over the borders from upstream countries (UNEP, 2007). These water resources are subject to variations in environmental and climate change, with the share of rainfall erratic and prone to drought spells. Sudan also possesses significant groundwater resources (the deep Nubian sandstone aquifer and the Umm Rawaba systems). These freshwater ecosystems provide significant development benefits as it provides energy in the form of electricity and irrigation for agricultural practices. However there has been a decrease in inland waters due to harsh climatic conditions over the years.

Identification and protection of key biodiversity areas will help prevent decline in habitat quality and species. Sustainable agricultural practices, wastewater treatment, sustainable utilization of freshwater bodies, both in the short-term and long-term, is essential in the management of these ecosystems. There is a need to raise awareness on the usefulness of these water resources and how to manage them. Finally, further research should be undertaken to fill the lack of information on some data deficient species in the region (García *et al.*, 2010).

3.4.1.2.3. Shelf ecosystem

<u>Status and trends:</u> Self-ecosystems current and future status are stable in Sudan and in progress in Mauritania. In Mauritania, only a few groves of mangroves forests are found in the south of Mauritania, in the Senegal Delta, along the estuary of Ntiallakh. The major species is *Avicennia germinans* (Least Concern). Its vitality is remarkable according to its biogeographical limit (Dahdouh-Guebas *et al.*, 2001). Archaeological sites (kjokkenmodding) testify more extended mangroves in the past, and harvesting of cockles (*Anadara senilis*) and oysters (*Crassostrea gazar*), notably in Chat Tboul.

Mangroves have been largely destroyed by the Diama and Manantali dams, built along the Senegal River, but now they are recovering, thanks to their protected status (belonging to Diawling National parks) - a programme of restoration conducted by IUCN in the 1990s (Hamerlynck *et al.*, 2003) and more recently, thanks to the intrusion of salty water, due to the breach across the Barbarie Tongue opened in 2003 (Sy *et al.*, 2015). The Senegal River delta is home of over 3 million wintering shorebirds; at least 108 bird species of nesting piscivorous birds and is one of the 3 transfrontier Biosphere Reserves of Africa (Bouamrane *et al.*, 2016). In Sudan, mangroves are dominated by *Avicennia marina* (Least Concern), along the coast from Mohammed Qol north of Port Sudan to Shabarango-Gafud south of Suakin. Mangrove lagoons and channels are occupied by numerous fish species including many commercially important species (e.g., *Acanthopagrus berda* (Least Concern), *Chanos chanos* (Least Concern), *Crenidens crenidens* (Least Concern), *Hypoatherina temminckii*, *Leiognathus equulus* (Least Concern), *Terapon jarbua* (Least Concern), *Pomadasys commersonni* and some mugilid species). Most of the Sudan Mangroves are included in the national parks of Red Sea and could be stable (but no data available on the trends).

<u>Future dynamics:</u> Mangrove surfaces, still stable in Sudan or recovering in Mauritania, will expand thanks to saline intrusions, linked to the breach across the Barbarie Tongue in Mauritania (Sy *et al.*, 2015) and limited pressions.

3.4.1.2.4. Open Ocean

Status: North Africa is bordered by the Atlantic Ocean and the almost landlocked Mediterranean and Red seas that are connected by the Straits of Gibraltar and the Suez Canal. Morocco has a productive, nutrient-rich upwelling area off its Atlantic coast. The Mediterranean Sea is considered to be a low productivity ecosystem with intensive fishing its primary driving force (NOAA, 2003). It is relatively poor in marine resources except around the Nile Delta, where high nutrient outflows increase productivity (FAO, 2003). The reefs of the Red Sea provide some of the most productive coastal fisheries (UNEP, 2005a).

Trends and future dynamics: Reported marine fish production has increased overall during the period 1980–2003, totalling about 1.4 million tons in 2001 (FAO, 2005). Morocco (Atlantic and Mediterranean) is by far the largest producer. In 2001, its total marine fish production was 933,197 tons–a six-fold increase since 1961. In 2015, its production reached 1,355,393 tons (Arneri *et al.*, 2011). Among the pelagic fish, *Sardina pilchardus* (Least Concern) is the species most fished and Merluccidae for white fish (Arneri *et al*., 2011). Egypt (Mediterranean and Red Sea) is the second largest producer (FAO, 2005). Generally in the Mediterranean, total fish landings have increased steadily, not only due to greater fishing pressure, but also to higher nutrient input into a formerly low-nutrient sea (Alm, 2002). In the Red Sea, where the total fish landings amount to about 22,800 tons/year with 44% of the landings are coral reef-based (PERSGA/GEF, 2003).

The recent marine biota in the Mediterranean Sea is primarily derived from the Atlantic Ocean, but the wide range of climate and hydrology have contributed to the co-occurrence and survival of both temperate and subtropical organisms (Sara, 1985; Bianchi *et al.*, 2000). Approximately 17,000 marine species occur in the Mediterranean Sea, with 20.2% endemic (Coll *et al.*, 2010). Artisanal fisheries are still important in the Mediterranean and Red seas, but industrial fishing including foreign fleets is becoming prevalent (UNEP, 2005a). The Mediterranean Sea has a set of emblematic species of conservation concern, such as sea turtles, several cetaceans, and the Critically Endangered Mediterranean monk seal (*Monachus monachus*). It is the main spawning grounds of the eastern Atlantic bluefin tuna (*Thunnus thynnus*, Endangered). There are several unique and endangered habitats, including the seagrass meadows of the endemic *Posidonia oceanica* (Least Concern), vermetid reefs built by the endemic gastropod *Dendropoma petraeum* (Gabrié *et al.*, 2012). The invasion of alien species is a crucial factor that will continue to change the biodiversity of the Mediterranean, mainly in its eastern basin that can spread rapidly northwards and westwards due to the warming of the Mediterranean Sea. Most of the fish species, such as Tuna are ranking from fully exploited to overexploited, and are at a risk of falling into the category of depleted (FAO, 2016).

3.4.1.2.5. Deep sea

Status: The Mediterranean basin has been proposed as a hotspot of terrestrial and coastal marine biodiversity but has been supposed to be impoverished of deep-sea species richness. Benthic biodiversity (Prokaryotes, Foraminifera, Meiofauna, Macrofauna, and Megafauna) in different deep-sea ecosystems of the Mediterranean Sea (200 to more than 4,000 metres depth), including open slopes, deep basins, canyons, cold seeps, seamounts, deep-water corals and deep-hypersaline anoxic basins are evaluated and analysed overall longitudinal and bathymetric patterns (Danovaro *et al.*, 2010). The overall deep-sea Mediterranean biodiversity (excluding prokaryotes) reaches approximately 2,805 species of which about 66% is still undiscovered. Among the biotic components investigated (prokaryotes excluded), most of the unknown species are within the phylum Nematoda, followed by

Foraminifera, but an important fraction of macrofaunal and megafaunal species also remains unknown (Danovaro *et al.*, 2010).

Trends and future dynamics: In contrast to what was expected from the sharp decrease in organic carbon fluxes and reduced faunal abundance, the deep-sea biodiversity of both the eastern and the western basins of the Mediterranean Sea is similarly high (Danovaro *et al.*, 2010). All of the biodiversity components, except Bacteria and Archaea, displayed a decreasing pattern with increasing water depth, but to a different extent for each component. Unlike patterns observed for faunal abundance, highest negative values of the slopes of the biodiversity patterns were observed for Meiofauna, followed by Macrofauna and Megafauna.

3.4.2. Central Africa

3.4.2.1. Terrestrial

3.4.2.1.1. Tropical and subtropical dry and humid forest

Status: The rainforests in Central Africa (178,564 million hectares) account for up to 89% of Africa's tropical rainforests (Mayaux *et al.*, 2013), constituting approximately 20% of the total global tropical rainforest area (FAO-ITTO, 2011). This is largely concentrated in the Congo Basin, which is the second largest rainforest in the world after the Amazon (FAO, 2011; Mayaux *et al.*, 2013). Much of Congo Basin rainforest falls within the Democratic Republic of Congo (DRC), accounting for some 53.6% of Africa's rainforests. There are, however, also significant areas of forest in Gabon, the Republic of Congo, Cameroon, the Central African Republic and Equatorial Guinea (Mayaux *et al.*, 2013). Currently, approximately 22.96 million hectares of Central Africa's forests have been designated as protected areas, and six of these are classified as United Nations World Heritage Sites (UNESCO, 2010). Cameroon, for example, has 18 national parks, some of which provide key protection in forest areas for flora and fauna species (a number of which are threatened–see below) (Mallon *et al.*, 2015). The Congo Basin rainforest is home to 493 species of mammals, 1,100 species of birds (including 5 families endemic to Africa), and 288 species of amphibians (Mayaux *et al.*, 2013; European Commission, 2015). The lowland forests in Central Africa contain around 10,000 plant species, 30% of which are found nowhere else in the world, while the Afromontane forests contain approximately 4,000 species (70% are endemic) (European Commission, 2015). Central Africa's rainforests store an estimated 39.2 GT of carbon in their vegetation and tree trunks, corresponding to 78.5% of the total aboveground carbon storage in Africa (Mayaux *et al.*, 2013). Approximately 30 million people, belonging to over 150 different ethnic groups, live in the Central African rainforests (UNESCO, 2010).

Trends: The extent of Central African rainforests has been decreasing, with an annual deforestation rate of 0.11%, accounting for 50-60% of the total deforested area in Africa from 2000-2010 (Mayaux *et al.*, 2013) (as well as previous deforestation rates of 0.16% for the 1990–2000 period, which may show some improvement at a regional scale). The area showing the most rapid change has been northern Congo, where a substantial increase in the rate of road construction has been observed; as well as major pressures around mining and primary industries (Mayaux *et al.*, 2013; Mallon *et al.*, 2015). The biodiversity in Central Africa associated with forest areas is also declining. Specifically, 11.4% of mammal species, 1.4% of bird species and 15.3% of amphibian species are threatened with extinction (Mayaux *et al.*, 2013). Central Africa currently has the most striking rates of decline/loss of large vertebrates (defaunation) in tropical rainforests (Malhi *et al.*, 2013). For instance, 62% of Central Africa's forest elephants (*Loxodonta cyclotis*, Vulnerable) are being lost from 2002 to 2011 (Maisels *et al.*, 2013), ape populations declined by 50% in Gabon over 1984–2000 (Walsh *et al.*, 2003), and about

178 species are affected by bushmeat hunting (Abernethy *et al.*, 2013). Up to 4.5 million tons of bushmeat are estimated to be extracted annually from the Central African forests, with an estimated annual value of up to $205 million (European Commission, 2015).

Future dynamics: Given the current known state and the trend in the past decades, the biodiversity of the tropical region of Central Africa may decline at an alarming rate in the near future, particularly given emerging changes in drivers (Chapters 4 & 5; SPM section B). Such a decline is likely to have critical repercussions for both ecological and human communities. For example, recent studies have already shown that the loss of large mammals, due to hunting, results in the decrease of seedling establishment for commercially important tree species in the Afrotropical forest of Gabon (Rosin *et al.*, 2016).

3.4.2.1.2. High mountain habitats

Status: The Albertine Rift Mountains ecoregion is an area of exceptional faunal and moderate floral endemism. These mountains also support the Mountain gorilla (*Gorilla beringei*, Critically Endangered), one of the most critically threatened large mammals in Africa (Mayaux *et al.*, 2013; Mallon *et al.*, 2015). The mountain chain comprising the Albertine Rift straddles the borders of five different nations, providing significant challenges for effectively transboundary management of high mountain forest found here (Mallon *et al.*, 2015). The Albertine Rift forms the epicentre of Africa's montane rainforest circle. Both its fauna and flora have links to the west and southwest with Cameroon and Angola, to the northeast with the Kenyan Highlands, and the southeast with the Eastern Arc Mountains, and ultimately via the Malawi Rift with southern Africa (Dowsett, 1986, Kingdon, 1989). The Albertine Rift is dominated by a series of mountain chains, originating on the Lendu Plateau in northern Uganda/DRC (Bober *et al.*, 2001), and running south through the Ruwenzori mountains of Uganda and the eastern part of the Democratic Republic of Congo (03°N, 30°E), western Rwanda and Burundi, to some isolated massifs on the shores of Lake Tanganyika (to 08°S). The mountain chain is a World Wide Fund Ecoregion, and is considered by Birdlife International to be an endemic bird area (Plumptre *et al.*, 2006). It is dominated by montane rainforest and medium altitudes (White, 1983), but in the west, marginal fringes of the Guineo-Congolian rainforest impinge on the lower slopes (down from 500–800 metres), and forest/savanna mosaic habitats border it to the east in Uganda, Rwanda and Burundi. At altitudes above 3,500 metres, montane rainforest grades through Juniper forest and Ericaceous Heathland into the tussock grass and Giant Lobelia dominated altimontane vegetation of the Ruwenzori-Virunga Montane Moorland ecoregion. Some details of the vegetation composition in the Albertine Rift Mountains are found in Lind *et al.* (1974), Langdale-Brown *et al.* (1964) and White (1983); as well as in Plumptre *et al.* (2006).

The ecoregion is the most species-rich region in Africa for vertebrates, and contains a number of endemic and threatened species (Plumptre *et al.*, 2006). For example, Bwindi Forest in Uganda supports an estimated 1,000 plant species; eight of these are tree species only found locally (WWF *et al*., 1994). Endemism is found at all altitudes, and extends markedly into the lower altitude forests on the western margins, which form a border with the Congo Basin lowland forests (Prigogine, 1985; Vande weghe, 1988a & b). The amphibians with 32 strict endemics spread across 12 genera, and a further seven near endemics, have the highest number of range-restricted species. The bulk of these endemics consist of the highly variable Reed Frogs (*Hyperolius*, 9 strict endemics), the Screeching frogs (*Phrynobatrachus*, 7 strict endemics) and the River Frogs (*Anthroleptis*, 5 strict endemics) and Clawed Toads (*Xenopus*, 3 strict endemics). Birds also possess exceptional levels of endemism in this area, with 30 strict endemics and another 16 near endemics (Bober *et al.*, 2001 and references therein). The endemic mammalian community contains 25 strictly endemic species and a further 11 species regarded as near-endemics

(WWF *et al*., 1994). The endemic mammal fauna is dominated by small-mammals, with 10 of the species being shrews, and 12 species being rodents. One of only two species of the family Tenrecidae on mainland Africa is also strictly endemic to these mountains, the Ruwenzori otter shrew (*Micropotamogale ruwenzorii*, Least Concern). The primate fauna further includes the owl-faced monkey (*Cercopithecus hamlyni*, Vulnerable) which has an endangered subspecies (*C. h. kahuziensis*) in the ecoregion, and L'Hoest's monkey (*Cercopithecus lhoesti*, Vulnerable).

Some of the easternmost populations of chimpanzee (*Pan troglodytes*, Endangered) also occur in this ecoregion (Harcourt *et al.*, 1983; Aveling *et al.*, 1984; Aveling *et al.*, 1989; McNeilage, 1996; Hall *et al.*, 1998a & b). The Albertine Rift endemic duiker *Cephalophus rubidus* may also venture into the upper parts of this ecoregion from the higher altitude heathland areas that are its more typical home. In comparison to the other vertebrate groups, the number of endemic reptiles is relatively low, with 11 strict endemics. These include four species of chameleons (*Chamaeleo* spp.) and four species of skinks in the genus *Leptosiaphos*. However, given the very high rates of endemism in other vertebrate groups, the number of endemics may more reflect the relatively low rates of biological collecting, rather than the true numbers of reptile endemics.

Trends: Key threats in this area are largely anthropogenic, including war, civil conflict, growth of extractive industries (including conversion to agriculture and artisanal mining), and hunting (Plumptre *et al.*, 2006). A number of large mammals in this area have been hunted to low populations or to extinction (Plumptre *et al.*, 2006). Conversion to crop-land has been evident in parts of the area in recent decades. Interestingly, Mayaux et al (2013) observed that Central Africa's forests remain largely intact (Mallon *et al.*, 2015). However, in parts of the high mountain forest region where rural populations are increasing, we see an expansion of agricultural activities and increases in deforestation (Mallon *et al.*, 2015). Bushmeat hunting has had further significant impacts in this area (Mallon *et al.*, 2015); exacerbated by increases, in certain areas, of extractive activities (largely mining and timber) (Chapters 4 & 5; SPM sections B & D). Significant challenges in this area, including a key site such as the Virunga Landscape (one of the most species-rich regions on earth; Plumptre *et al.*, 2006), include taking a landscape approach, and managing connected protected and non-protected areas (Plumptre *et al.*, 2006; Mallon *et al.*, 2015). Where Rwanda, Uganda and the DRC meet, for example, provides a key example of the challenges in taking such an approach–three different countries with valuable areas of high mountain forest, yet different trends in driving forces of change, in hunting and extractive industries, and different approaches to environmental governance.

Future dynamics: There is largescale agreement amongst climate models for increases in minimum, maximum and average temperature across all seasons under climate change (Niang *et al.*, 2014; Conway *et al.*, 2015; SPM section B). In addition, primary industry activities are likely to increase in many areas (see, for example, the example of Virunga National Park above); without increased intervention and management. The coupled impact of increased temperatures on High Mountain Forest, with altitudinal shifting of habitat, together with increased extractive activities in certain areas, increases the likelihood that existing species loss in these areas may worsen (Niang *et al*., 2014; SPM sections B & D).

3.4.2.1.3. Savannah and grassland

Status: The savannah region in Central Africa extends from the Congo watershed to the Cameroon highlands; and extends east through the Central African Republic and north-eastern Democratic Republic of Congo (WWF, 2017b). The woodland savanna is dominated by *Acacia albida*, *A. senegal*, and *A. nilotica*. Other species include: *Balanites aegyptiaca, Ziziphus spp., Crateva adansonii*, *Celtis integrifolia, Ficus spp.,* and *Khaya senegalensis* (Culverwell, 1998). Key savannah and grassland mammals present in these areas include African elephant (Savanna elephant) (Mallon *et al.*, 2015; Figure 2.2), the Striped Hyaena, and the Lion (*Panthera leo*).

Trends: This terrestrial unit of analysis is currently decreasing due to increasing human population, political instability and civil wars, habitat conversion, overhunting and commercial logging (WWF, 2017b). A number of species within savannah and grassland areas is Central Africa show decline, including the Striped Hyaena (Mallon *et al.*, 2015) and the Lion (*Panthera leo*). Henschel *et al.* (2014) indicate that Lions are likely to now be extinct in the Congo Basin's rainforest –savannah mosaics. The African Wild Dog (*Lycaon pictus*) is now also considered to be extinct in the same area (Henschel *et al.*, 2014). Savanna elephants have been further significantly impacted, as in other areas, through increases in poaching and shrinking and shifting habitat (Mallon *et al.*, 2015).

Future dynamics: The future trend of biodiversity in this ecosystem unit of analysis will depend, for example, on the future dynamics of population growth, political stability and habitat conversion (WWF, 2017b). Political instability in the region remains a significant problem, as evidenced by the crisis in the Central African Republic. Habitat loss is also increasing within the region (WWF, 2017b), hence it is expected that the savannas and grasslands within the region will continue to decline in extent with associated biodiversity loss. Extractive industries in this area (largely mining) is likely to continue to impact habitat loss and associated effects on ecosystem services, complicated by climate change (Niang *et al.*, 2014; Chapter 4; SPM sections B &D).

3.4.2.1.4. Dryland and desert

Status: In Central Africa, drylands and deserts are represented by the Sahelian transitional zone which covers an area of 20,000 km^2, in which the major portion is located in Chad–thus not within Central Africa (WWF, 2017b). The region supports endemic flora and fauna and provides important habitat for larger antelopes such as Addax (*Addax nasomaculatus*, Critically Endangered), Dama gazelle (*Gazella dama*, Critically Endangered), Dorcas gazelle (*Gazella Dorcas*, Vulnerable) and red-fronted gazelle (*Gazella rufifrons*, Vulnerable) (WWF, 2017b).

Trends and future dynamics: Most large animal species are declining due to competition with livestock (WWF, 2017b). In the part of the Sahelian transitional zone that falls within what we consider as Central Africa in IPBES, we see similar challenges around habitat fragmentation, cultivation and extractive industries as described above (Mallon *et al.*, 2015). For example, the Striped Hyaena, as mentioned previously, is distributed sparsely and declining (Mallon *et al.*, 2015), while the Common Leopard (*Panthera pardus*, Vulnerable) has undergone a marked range reduction throughout the Sahelian transitional zone (Mallon *et al.*, 2015). With increases in extractive industry activity, complicated by climate change, we would expect such trends to continue in absence of increasingly effective landscape scale and transboundary approaches (Niang *et al.*, 2014; Chapters 4 & 5; SPM sections B & D).

3.4.2.1.5. Urban/Semi-urban

Status and trends: In the Central African region, the number of cities sized at 1.5 million has increased between 1970, 1990 and 2014 by 10 million inhabitants (Seto *et al.*, 2012). In 2014, Kinshasa was established as a megacity; and currently stands as the only megacity in this region at present (Seto *et al.*, 2012). In 2013, Kinshasa's urban extent stood at 45,681 hectares, with an annual average increase rate of 3.5% since 2000. Density in Kinshasa has increased at 3.7% as an annual average since 2000; and is expected to continue (Seto *et al.*, 2012).

Future dynamics: Future projections for Central Africa show a likely increase in the number of cities sized at 1.5 million (Chapter 4, section 4.4.4.1; Chapter 5; SPM sections B & D). Seto *et al.* (2012) indicate the northern shores of Lake Victoria in Kenya and Uganda) as one of five regions in Africa where rates of increases in urban land cover are predicted to be the highest on the continent–at 590% relative to 2000 levels (Seto *et al.*, 2012). Such projected increases are likely to have significant implications for biodiversity in the Great Lakes region, with both terrestrial and aquatic impacts (particularly concerning in an area with such rich and diverse fish fauna, and one so central to food and livelihoods security).

3.4.2.1.6. Cultivated lands

Status and trends: As in other subregions of the continent, agrobiodiversity in the Central African region is of great significance, as it is the largest contributor to food production. Central Africa is home to a variety of crops, such as cereals, oilseeds, roots and tubers, pulses, fruit and vegetables and other cash crops; with oil seeds constituting the biggest fraction of crop production in the subregion (OECD-FAO, 2016). Poultry in Central Africa contributes extensively to the sub-Saharan livestock production value, with up to 45% contribution to the total value (OECD-FAO, 2016). In the subregion, agroforestry systems are equally important, as they may be an effective means to ensure rural livelihoods while maintaining forest cover and biodiversity (Asaa *et al.*, 2011). A number of species in the subregion form part of agroforestry systems. Fruit trees include African bush mango (*Irvingia gabonensis*), Safou/butterfruit (*Dacryodes edulis*, Lower Risk/Near threatened), Kola nut, Bitter kola (*Garcina kola*), and Njangsa (*Ricinodendron heudelotti*) (Asaah *et al.*, 2011).

Future dynamics: The overall extension of crop production area is projected to slow in the sub-Saharan Africa region, due to the increasing costs of converting arable land to production land (OECD-FAO, 2016). Additional crop area is mostly allocated to staple crops such as coarse grains. However, cultivated land in Central Africa is projected to expand, with the greatest increase being attributed to rice, roots and tubers crop production areas (OECD-FAO, 2016).

3.4.2.2. Aquatic (Freshwater, Marine and Coastal)

3.4.2.2.1. Wetlands

Status and trends: The wetlands in the Central Congo Basin, the Cuvette Centrale depression, forms one of the most extensive regions of swamp forest, extending at approximately 145,500 km^2 (Dargie *et al.*, 2017). The Cuvette Centrale depression stores approximately 30.6 pentagrams of carbon below ground, similar to the above-ground carbon stocks of the tropical forests of the entire Congo Basin (Dargie *et al.*, 2017). Collectively, Central African countries host approximately 4,214 km^2 of mangroves, with only a few being protected. Fish, wood, charcoal for domestic cooking and fish smoking and poles for housing are key uses of mangroves, among others. The delta of the Ogooué River in Gabon is Africa’s second largest delta after the Niger, covering over 5,000 km^2 of flooded forests, swamps, lagoons, lakes and mangroves. The delta of the Ogooué River in Gabon is among the world’s most important site for nesting marine turtles, particularly leatherbacks (Mayaux *et al.*, 2013). Despite the economic and ecological importance of wetlands, however, there are many uncertainties as to their extent, distribution, ecological and physical functions (Junk *et al.*, 2005). Political instability in most of the humid tropical countries during the last five decades, poor infrastructure, and as well as difficult access may account in part for the scientific inattention (Campbell, 2005).

Future dynamics: Climate change is projected to impact mangrove and wetland ecosystems significantly, with changes in temperatures, as well as coastal sea level rise and saline intrusion dynamics (Niang *et al.*, 2014; Chapter 4, section 4.2.2.2; SPM sections B & D). For example, Niang *et al.* (2014) show robust evidence for projected dieback of the seaward edges of mangroves in the Cameroon, with sea level rise as the potential driver. As always, climate change occurs in tandem with changes in other stressors, including human settlement dynamics, and increases in extractive industries (Mallon *et al.*, 2015; Chapter 4).

3.4.2.2.2. Inland surface waters and water bodies/freshwater

Status and trends: The major waterways in Central Africa range from the Niger-Benue, Chad and Upper Nile drainage systems, to the mouth of the Congo and other rivers from Equatorial Guinea and DRC (Darwall *et al.*, 2009). The Congo Basin and its territories carry about 30% of Africa's surface flow due to high rainfall and less evaporation (Thieme *et al.*, 2010). Some of the well-known rivers of Central Africa are the Goose, Sanaga, Mungo and Wuori rivers (Staissny *et al.*, 2007). Besides the extensive networks or rivers. Central Africa has several lake systems e.g., Lake Nyos, Lake Tele, Lakes Tsumba and Mai Ndombé in DRC.

Inland waters in Central Africa support the highest freshwater biodiversity on the continent, with approximately 1,000 fish species, 400 aquatic mammalian species, 1,000 waterbirds and over 10,000 aquatic vascular plants (CARPE, 2001; AfDB, 2006). There are at least 73 Important Bird Areas in Central Africa region (CARPE, 2001). The geographic extent, dense hydrographic network, and diversity of river types and available habitats, are among the several existing several factors that contribute to the high richness of freshwater species in the Lower Guinea, and more noticeably, Congo provinces. A significant proportion of freshwater biodiversity is threatened due to loss of riparian habitats through deforestation, and the reduction of water quality through pollution (e.g., from mining activities, human settlement, and runoff of agricultural fertilisers), as well as increased sediment loads (caused by erosion of deforested and farmed land) (Brummett *et al.*, 2009).

Future dynamics: Projected increases in human settlement (see section on urbanisation above) and extractive industries (Chapters 4 & 5; SPM sections B & D) are likely to continue the trend of negative impacts on freshwater biodiversity. A particularly critical area in this regard, given projections of urbanisation and settlement growth, are the north shores of Lake Victoria (see section on projections of urbanisation). Complicating such future changes are the likely impacts of climate change on freshwater biodiversity in this region. Niang *et al.* (2014) cite significant projected impacts of climate change on freshwater ecosystems, with existing impacts already evident and likely to increase in severity in Lake Victoria and Lake Kivu (Niang *et al.*, 2014; Chapter 3, section 3.5.2.4), largely driven by increased water temperatures (a robust finding, since agreement amongst models regarding increased average, minimum and maximum temperatures is high – see, for example, Conway *et al.*, (2015) for Tanzania). Changes in thermal stratification in these lakes is also likely to continue under increased temperatures, with significant impacts on freshwater ecosystems, and likely impacts on fisheries in these lakes (complicated by continuing drivers of overfishing in certain areas, invasive species and pollution) (Niang *et al.*, 2014).

3.4.2.2.3. Shelf ecosystem

Status and trends*:* Collectively, these countries host approximately 4,214 km^2 of mangroves, with a few only being protected. The most important remaining blocks of habitat are found in the Niger River Delta in Nigeria, to the east of the mouth of the Cross River in Nigeria and Cameroon, around Doula in

Cameroon, and the Muni Estuary and Como River in Gabon. Smaller fragments of shelf ecosystems are also found in Ghana, Conkouati lagoons of Congo, and in Angola. Five species of mangroves in three families are found in this region, including *Rhizophora racemose* (Least Concern)*, R. mangle, and R. harrisonii, Avicennia germinans* and *Laguncularia racemosa* (Least Concern), as well as an introduced species, *Nypa fruticans (*Least Concern) (Table 3.9).

Table 3.9: African biogeographical regions: Atlantic mangrove (or western group (and Pacific or Eastern group). Source: Saenger *et al.* (1995); Cormier-Salem (1999); Ndour *et al.* (2001); Giri *et al.* (2008); Spalding *et al.* (2010); Hoppe-Speer *et al.* (2015).

	Western group		**Eastern group**	
Coastal areas	**Tropical Atlantic** East of Atlantic Ocean : - West Africa; - Central Africa - Northern Africa (Mauritania)		**Pacific** West of Pacific Ocean/ Indian Ocean : - Eastern Africa and islands; - Southern Africa - Northern Africa (Sudan)	
	Genus	**Species**	**Genus**	**Species**
Family	**Avicenniaceae**			
	Avicennia	*A. africana* *A. germinans* *A. nitida*	***Avicennia***	*A. alba* *A. marina* *A. officinalis*
	Bombacaceae			
			Lumnitzera	*L. racemosa*
	Combretaceae			
	Laguncularia	*L. racemosa*		
	Conocarpus*	*C. erectus*		
	Lythrceae			
			Pemphis	*P. acidula*
	Meliaceae			
			Xylocarpus	*X. obovatus* *X. granatum* *X. moluccensis*
	Rhizophoraceae			
			Bruguiera	*B. gymnorrhiza*
			Ceriops	*C. tagal* *C. somalensis*
			Kandelia	*K. candel*
	Rhizophora	*R. harrisonii* *R. mangle* *R. racemosa*	***Rhizophora***	*R. apiculata* *R. mucronata* *R. stylosa*
	Sonneratiaceae			
			Sonneratia	*S. alba*
	Sterculiaceae			
			Heritieria	*H. littoralis*
	Total	**8**		**17**

A unique feature of shelf ecosystems in Gabon is the fact that elephants, gorillas, chimpanzees, hippo, forest buffalo and Nile crocodile can often be observed on the beaches. These beaches are also among the world's most important for nesting marine turtles, particularly leatherbacks (Mayaux *et al.*, 2013). Urbanisation and pollution (contaminants) are the main threats.

Future dynamics: At the current rate, the aquatic units of analysis remain under threat of further decline because of increasing urbanisation, pollution and exploitation. Nevertheless, positive signals are noted with the development of integrated conservation project, such as Emerald Arc project that aims to integrate coastal ecosystems and protected areas in the sustainable development of the city of Libreville.

3.4.2.2.4. Open Ocean

Studies on marine species and their ecology in central Africa have been completely neglected. Whenever this information has been obtained, it has been limited to economically useful species (Gabche, 2003; Ogandagas, 2003). Marine resources include commercially valuable fish that are exploited at artisanal and industrial scales. The exploitable species of aquatic fauna within the marine and coastal ecosystems consist essentially of fishes, shrimps and molluscs. Currently the Carangidae, Carcharinidae, Clupeidae, Elopidae, Ephippidae, Haemulidae, Lutjanidae, Paralichthyidae, Polynemidae, Mugilidae, Sciaenidae families are overexploited (Ogandagas, 2003). An accelerated growth of coastal populations has led to crowded conditions where the poor depend on subsistence activities such as fishing, farming, sand and salt mining and production of charcoal (Sherman *et al*., 2008).

3.4.2.2.5. Deep-sea

The deep-sea biological communities in Central Africa are relatively unexplored with available records mainly from geological surveys for prospecting and drilling of hydrocarbons and from historical oceanographic cruises undertaking global navigations. In general, the structure, density and vertical distribution patterns of communities depend on the topographic features of the seabed and source of nutrients. The Congo deep-sea fan, for example, an area of 2,500 km^2 at 47,000 metres depth and 750–800 km offshore, has a unique habitat influenced by high inputs of organic carbon originating from the Congo River by turbidity currents, with high density assemblages of two large sized symbiotic Vesicomyidae bivalve species and microbial mats (Rabouille *et al.*, 2016). Although there are no true corals along the continental margin, there have been new observations of deep-water coral reefs *Lopheliapertusa* along the Angola margin that are generally associated with cold seep environments (Le Guillox *et al.*, 2009).

3.4.3. East Africa and adjacent islands

3.4.3.1. Terrestrial

3.4.3.1.1. Tropical and subtropical dry and humid forest

Status: The tropical and subtropical humid forests of East Africa and adjacent islands comprise lowland and montane forest habitats, which are found in fragmented patches due to human disturbance (lowland forests) or to natural isolation (mountain forests). The East African forests form a small proportion of the forests in Africa–for example representing only 4% of the African rainforests (Mayaux *et al.*, 2013). However the lowland and mountain forests of East Africa and adjacent islands are rich in biodiversity.

The Malagasy eastern rainforests, for example, contain 159 species of mammals, 217 species of birds and 219 species of amphibians (Mayaux *et al.*, 2013) and hold 5% of the world's plant species (Brown *et al.*, 2004), 82% of which are endemic to Madagascar (Callamander *et al.*, 2011). High rates of species endemism are also found in the East African mountain forests in Tanzania and Kenya (Eastern Arc mountains) and Uganda, Rwanda, Burundi and DRC (Albertine Rift Mountains).

Most of the tropical dry forests in East Africa and adjacent islands are located in northern and western Madagascar (Crowley, 2004). They are found within a region that covers 31,970 km^2 of land (Madagascar, 2014), but most of the remaining forest is fragmented with patches up to 35 km^2 (WWF, 2017a). The dry forests of western Madagascar are some of the world's richest and most distinctive, with high local plant and animal endemism, which includes 101 mammal species, 154 reptile species, 73 bird species, 34 amphibian species and 198 plant species (IUCN, 2017). This region also contains important habitat for 131 of the 186 resident terrestrial bird species in Madagascar (Langrand, 1990). It is also the primary habitat for the island's largest predator, the fossa (*Cryptoprocta ferox*, Vulnerable), the endemic and Critically Endangered Madagascar side neck turtle (*Erymnochelys madagascariensis*), and one of the most Critically Endangered reptiles in the world, the ploughshare tortoise (*Astrochelys yniphora*).

Trends and future dynamics: Similar to other tropical regions, the extent of the lowland and mountain rainforests and dry forests in East Africa has been decreasing. For example, Malagasy eastern rainforests decreased by 1.69% annually from 1990–2000 and 1.08% from 2000–2010 (Mayaux *et al.*, 2013), and an estimated 97% of Malagasy dry western forests have been destroyed since human settlement (WWF, 2017c), with an annual deforestation rate of 0.75% from 1990–2000 (Gorenflo *et al.*, 2011).

In the eastern African coastal forests loss is primarily through conversion to farmland, mainly through shifting cultivations. Overall, coastal forest cover in Tanzania declined by over a third from 420,765 hectares in 1990 to 358,333 hectares in 2000 and to 273,709 hectares in 2007. The rate of deforestation has been lower within Tanzanian reserves: 0.2 and 0.4%/year during 1990–2000 and 2000–2007, respectively, compared to 1.3 and 0.6%/year outside reserves during the same periods (Godoy *et al.*, 2012; Burgess *et al.*, 2017). In the same forests, estimates by Burgess *et al.* (2010) of the total carbon emissions per annum from the Coastal forest areas of Tanzania were 631,933 tons of CO_2/year, for the period 1990–2000 and had declined to 198,154 tons of CO_2/year by the period 2000–2007. Elsewhere, monitoring data collected over a three year period from 2005–2008 in 67 permanent transects in Arabuko-Sokoke forest by Virani *et al.* (2010) showed a steady but not statistically significant decline in Sokoke Scops-Owl densities.

3.4.3.1.2. High mountain habitats

Status: East Africa and adjacent islands are home to the three highest mountains on the continent: Kilimanjaro (5,895 metres), Mount Kenya (5,119 metres) and the Rwenzori Mountains (5,109 metres) (Alweny *et al.*, 2014; UNEP, 2014). There are also extensive highland regions in Ethiopia. These mountains are the source of many of the major rivers in the region, such as the Nile, and are rich in biodiversity.

The mountain areas of the Eastern African region (and also into Arabia) have been grouped together in the 'Eastern Afromontane' hotspot by Conservation International (Mittermeier *et al.*, 2004). The flora of the Eastern Afromontane shows great continuity across the montane massifs, with its composition changing with increasing altitude. At the highest elevations, such as the Rwenzori Mountains, the

Aberdares, Mt. Elgon, Mt. Kilimanjaro, Mt. Kenya, and the Bale and Simien Mountains in Ethiopia, Afro-alpine vegetation typically occurs above 3,400 metres. Afro-alpine vegetation is characterized by the presence of giant senecios (*Dendrosenecio* spp.), giant lobelias (*Lobelia* spp.), and *Helichrysum* scrub (McGinley, 2009). There are also about 13 endemic species of African primroses (*Streptocarpus* spp.) in the Eastern Arc Mountains, and 18 endemic species of *Impatiens* in the Albertine Rift (McGinley, 2009). The Eastern Afromontane hotspot is also home to nearly 500 mammal species, more than 100 of which are endemic to the region. Although several of Africa‘s larger flagship mammals, including the African bush elephant (*Loxodonta africana*, Vulnerable) and leopard (*Panthera pardus*, Vulnerable), are found in this hotspot, the majority of threatened species are primates and smaller mammals. The total birds number exceeds the 1,300 species initially reported by Mittermeier *et al.* (2004), and includes 157 endemics (Lincoln Fishpool, personal communication), 102 of which are restricted range species found within the eight endemic Bird Areas recognised by BirdLife International. New species continue to be discovered, particularly from the Eastern Arc Mountains of Tanzania (Bowie *et al.*, 2004, 2009). Nearly 350 reptile species are found in the Eastern Afromontane hotspot. More than 90 species are endemic, most of which are chameleons. The Eastern Afromontane hotspot is also home to more than 323 amphibian species, more than 100 of which are endemic.

There are three main areas of biological rich highland forest and moorland habitats in the region: The Ethiopian Highlands, the Albertine Rift and the Eastern Arc Mountains. These are presented in turn below.

The Ethiopian Highlands cover an area of 490,000 km^2 (Subhatu *et al.*, 2017) straddling Ethiopia and Eritrea, harbour an estimated 5,200 plant species, of which at least 200 are endemic. The genus *Senecio* is particularly diverse, with a dozen species found nowhere else. This area also has a monotypic endemic genus, *Nephrophyllum abyssinicum*, which is found on heavily grazed pastures, open ground, and rocky areas on steep slopes between 1,650 and 2,700 metres. Many species common in montane forest, such as trees of the genera *Podocarpus* and *Juniperus* have economic importance, while several crops including coffee (*Coffea arabica*, Least Concern) and tef (*Eragrostis tef*) from the Ethiopian Highlands have been domesticated (McGinley, 2009). A zone of bamboo is often found between 2,000 and 3,000 metres, above which there is often a *Hagenia* forest zone up to 3,600 metres.

More than 30 of the nearly 200 mammals found in the Ethiopian Highlands are found nowhere else, including a remarkable six endemic genera, four of which are monotypic: three rodents (*Megadendromus*, *Muriculus* (Least Concern) and *Nilopegamys* (Critically Endangered) and one primate, the gelada (*Theropithecus gelada*, Least Concern). The gelada is peculiar in that it is the only remaining primate to feed exclusively on plants–mostly grasses (Gippoliti *et al.*, 2008). The Ethiopian wolf (*Canis simensis*, Endangered) is an endemic species found in the Afro-alpine ecosystem of the Ethiopian Highlands; with around 440 individuals in seven small and isolated populations, this wolf is the rarest canid in the world; with around 440 individuals in seven small and isolated populations, this wolf is the rarest canid in the world (Sillero-Zubiri *et al.*, 1997).

About 680 species of birds are found in the Ethiopian Highlands, some 30 of which are endemic. Four endemic genera are found in this part of the hotspot, including three that are relatively widespread within it (*Cyanochen* (Vulnerable), *Rougetius* (Near Threatened) and *Parophasma* (Least Concern)) and one that has a localized distribution in the south (*Zavattariornis*, Endangered). Six endemic genera of amphibians are found in the Ethiopian Highlands, four of which are monotypic (*Altiphrynoides*, *Spinophrynoides* (Critically Endangered), *Balebreviceps* (Critically Endangered) and *Ericabatrachus*, Critically Endangered), while the fifth, *Paracassina* (Vulnerable), is represented by two frog species world (Sillero-Zubiri *et al.*, 1997).

The Albertine Rift includes portions of Rwanda, Burundi, Uganda, Tanzania and the Democratic Republic of Congo and is formed along the Great Rift Valley, and contains considerable volcanism associated with the gradual splitting apart of Africa. The highlands have rich agricultural land, and as a result the region is a major exporter of tea and coffee. Biologically, it is famous for its outstanding species diversity and the large number of endemic species. The Albertine Rift is home to about 14% (about 5,800 species) of mainland Africa's plant species, with more than 550 endemic species, including three endemic genera: *Afroligusticum, Micractis* (Least Concern), *Rhaesteria* (Sillero-Zubiri *et al.*, 1997).

Nearly 40% of continental Africa‘s mammals are found in the Albertine Rift; this comprises more than 400 species, of which 45 are endemic. Most of these endemic mammals are shrews and rodents, including two monotypic endemic genera: the Ruwenzori shrew (*Ruwenzorisorex suncoides*, Vulnerable) and Delany‘s swamp mouse (*Delanymys brooksi*, Vulnerable). New species continue to be found and described, particularly in isolated highlands such as Itombwe and Kabobo in DRC. The forests of the Albertine Rift are also home to at least 27 primate species, including Hoests monkey (*Cercopithecus lhoesti*, Vulnerable), the owl-faced monkey (*C. hamlyni*, Vulnerable), and the golden monkey (*C. mitis kandti*, Endangered). However, the most charismatic flagship species of the Albertine Rift, and indeed of the entire hotspot, are the great apes. The population of the well-known mountain gorilla (*Gorilla beringei*, Critically Endangered) is limited to about 480 individuals in Virunga volcanoes and 300 individuals in Bwindi Impenetrable National Park. Grauer‘s gorilla (*G. b. graueri*, Endangered), which is found in the lowlands, was estimated at a population of 16,900 in eastern DRC in 1996, but has since suffered major declines as a result of hunting, as well as habitat loss and diseases. There are also small populations of robust chimpanzee (*Pan troglodytes schweinfurthii*, Endangered) in many of the Albertine Rift forests including into western Tanzania. Other mammals include the Ruwenzori duiker (*Cephalophus rubidus*, Endangered), which is restricted to the Rwenzori Mountains, and the Ruwenzori otter shrew (*Micropotamogale ruwenzorii*, Least Concern), one of only three representatives of the family Tenrecidae on the African mainland (McGinley, 2009).

The Albertine Rift is also extremely rich in birds; more than 1,074 species in 368 genera have been recorded from the area. Of these, 43 are restricted-range species endemic to the rift area, and these include three monotypic endemic genera: *Pseudocalyptomena* (Vulnerable), *Graueria* (Least Concern), and *Hemitesia* (Least Concern). Both the African green broadbill *(Pseudocalyptomena graueri*, Vulnerable*)* and short-tailed warbler *(Hemitesia neumanni*, Least Concern*)* are more closely related to Asian species than they are to any birds in Africa, while the affinities of Grauer’s Warbler *(Graueria vittata*, Least Concern*)* remain uncertain. A fourth species confined to the rift, the Congo bay-owl *(Phodilus prigoginei*, Endangered*)*, is one of only two species in the genus *Phodilus*.

Around 177 (14%) of Africa‘s reptile species live in the Albertine Rift, including about 18 endemic species. Five of these endemic species are chameleons, including the Rwenzori three-horned chameleon (*Chamaeleo johnstoni*, Least Concern). The very rare strange-horned chameleon (*Kinyongia xenorhina*, Near Threatened) is confined to the Rwenzori Mountains, where it has probably been over-collected for the wildlife trade (impacts not yet properly documented). The Albertine Rift contains 143 known species of amphibians, including 38 endemic species and three monotypic endemic genera: Parker‘s tree toad (*Laurentophryne parkeri*), the Itombwe golden frog (*Chrysobatrachus cupreonitens*, Endangered) and African painted frog (*Callixalus pictus*, Vulnerable).

The Eastern Arc Mountains and Southern Rift stretch from south-eastern Kenya to southern Tanzania and Malawi, with small outliers in eastern Zimbabwe and western Mozambique. The Eastern Arc Mountains have 3,473 species in 800 genera, of which at least 453 species and around 40 genera are believed to be endemic, including trees, shrubs and herbs. Endemism is lower in the Southern Rift, with perhaps only 100 endemic species. The Nyika Plateau supports nearly 215 orchid species, of which about four species are endemic. Many thousands of species of plants and animals are found in these forests and nowhere else on earth (EAMCEF, 2012), and these include at least 100 species of birds, mammals, amphibians and reptiles; at least 500 plants and huge numbers of smaller creatures including butterflies and millipedes.

The Eastern Arc Mountains hold 12 endemic mammal species (Rovero, 2015). Four species of primates are endemic to the Eastern Arc Mountains and Southern Rift: the kipunji monkey (*Rungwecebus kipunji* Critically Endangered), the sanje mangabey (*Cercocebus sanjei*, Endangered), the Udzungwa red colobus (*Procolobus gordonorum*, Endangered) and the mountain dwarf galago (*Galagoides orinus,* Near Threatened). Six shrew species are endemic to this part of the hotspot, including the desperate shrew (*Crocidura desperate*, Endangered), found only in the Udzungwa and Rungwe mountains, and Phillips' Congo shrew (*Congosorex phillipsorum,* Critically Endangered), known only from the highest altitude areas in the Udzungwa Mountains. Other notable mammals in the Eastern Arc include Abbott's duiker (*Cephalophus spadix*, Endangered) and the eastern tree hyrax (*Dendrohyrax validus*, Near Threatened). Several new mammal species have also been discovered in the past decade, including two possibly new species of dwarf galago (*Galagoides* spp.) in the Taita Hills and on Mount Rungwe, and the grey-faced elephant shrew (*Rhynchocyon udzungwensis*, Vulnerable) in the Udzungwa Mountains. The Eastern Arc has 21 endemic bird species and three endemic genera (*Xenoperdix* (Endangered), *Sceptomycter,* and *Modulatrix* (Vulnerable)) (Fuchs *et al.*, 2011).

Data compiled in 2010 show that 32 species of reptiles are endemic to the Eastern Arc Mountains, the majority of these being chameleons in the genera *Chamaeleo*, *Rhampholeon* and *Kinyonga* (MNRT, 2011). There are also endemic species of worm snakes (*typhlops*), geckos and colubrid snakes. The Southern Rift has fewer endemic species, but there are endemic chameleons on Mounts Mabu and Mulanje, including the Mulanje mountain chameleon (*Bradypodion mulanjense*) and the Malawi stumptail chameleon (*Rhampholeon platyceps*, Endangered). A new species of snake, *Atheris mabuensis,* is also known from Mount Mabu in Mozambique.

For the amphibians, there are more than 50 endemic species in the Eastern Arc Mountains, concentrated in the reed tree frogs (*Hyperolius*), forest tree frogs (*Leptopelis*), viviparous toads (*Nectophrynoides*), narrow-mouthed frogs (family Microhylidae) and caecilians. The Eastern Arc Mountains supports 50% of the members of the caecilian family, Scolecomorphidae, among which the genus *Scolecomorphus*, with three species, is endemic. The Eastern Arc Mountains and Southern Rift contain all species of the genus *Nectophrynoides*, which includes the majority of the world‘s viviparous (live-bearing) frogs. Seven new species of *Nectophrynoides* have been described since 2004 (Menegon *et al.*, 2004; Channing *et al.*, 2005; Menegon *et al.*, 2008). Another monotypic genus of toad, *Churamiti maridadi* (Critically Endangered), was discovered in the Ukaguru Mountains in 2002. In addition, three new species in the genus *Callulina* have recently been described (Loader *et al.*, 2010). Dozens of new species collected from the Eastern Arc Mountains remain to be described including more than 50 species of vertebrates, mainly amphibians and reptiles, but also some birds (Fjeldså *et al.*, 2010).

In addition to these three main massifs, a number of outlying mountains are part of this hotspot, including the Neogene volcanic of the Kenyan and Tanzanian Highlands (e.g., Mt Kilimanjaro, Mt Meru, Mt Kenya, Mt Elgon, Aberdares Range, and other peaks). Many of these massifs are volcanic in origin, and some are still active–especially in Virunga National Park (McGinley, 2009). Typically these newer mountains support much lower biodiversity values than the more ancient mountain blocks

Trends: There are relatively few studies of the trends in species in the mountains of Eastern Africa. In the Albertine Rift mountains and according to the IUCN Red List the mountain gorilla (*Gorilla beringei*, Critically Endangered) has suffered major declines as a result of hunting, habitat loss and degradation. Studies conducted by Borghesio *et al.* (2010) strongly suggest that a major population crash of the Critically Endangered Taita Apalis (*Apalis fuscigularis*, Critically Endangered) is underway. Compared with 2001, sighting rates in April-May 2009 had dropped by about 38%; repeated counts done in September–December 2009 and May–July 2010 showed even larger decreases, approaching 80%. This means that the global population of the species might now be only 60–130 individuals, almost all of which are located in a single forest, Ngangao, which is only about 120 hectares (BirdLife International, 2013).

In the Eastern Arc Mountains of Tanzania and Kenya, the forest has suffered an estimated 80% total loss in historical forest area and has lost 25% of forest area since 1955. Forest loss has not been even across all elevations. The upper montane zone (>1,800 metres) has lost 52% of its paleoecological forest area, 6% since 1955. Conversely, the submontane habitat (800–1,200 metres) has lost close to 93% of its paleoecological extent, 57% since 1955 (Newmark, 1998; Hall *et al.*, 2009). Losses were greatest, relative to original cover, in Taita Hills (98%), Ukaguru (90%), Mahenge (89%) and West Usambaras (84%). Only small declines are reported after 200 by Hall *et al.* (2009), mainly because all forest outside reserves has been cleared for farmland, leaving only the reserves and their habitats broadly intact.

3.4.3.1.3. Tropical and subtropical savannah and grasslands

Status: Savannas and grasslands dominate almost 75% of East Africa and adjacent islands (Reid *et al.*, 2005), covering an area of 527,000 km^2 (WWF, 2017b). They are highly diverse with regards to composition of plant species, with about 1,000 species of grass being endemic to the region (Boonman, 1993). The drier habitats are dominated by *Combretum*-*Acacia*-*Commiphora* bushlands and thickets (WWF, 2017b), and are found in the north of the eastern African region. The largest areas of savannah woodland in the central and southern parts of the region are termed the ‘miombo’ woodlands (Frost *et al.*, 1996; Timberlake *et al.*, 2011, 2014). ‘Miombo’ is the Swahili word for the tree genus Brachystegia. These woodlands are dominated by trees of the subfamily Caesalpinioideae, particularly miombo (*Brachystegia), Julbernardia* and *Isoberlinia*, and are mainly situated on the ancient African plateau at an elevation of 800 to 1,250 metres above sea level. Mean annual rainfall between 600 to 1,400 millimetres, occurring between the months of November and April, and temperatures in the warm sub-humid zone (24–27°C), characterize the climate (Frost *et al.*, 1996; Timberlake *et al.*, 2011; Timberlake *et al.*, 2014). The unimodal rainfall pattern with prolonged dry seasons, coupled with the well-developed grass layer, exacerbates the frequency of wide-spreading fires, which have both natural and anthropogenic causes. Fire and pastoralism are believed to have played integral roles in the structuring of the miombo ecoregion through the tens of thousands of years of anthropogenic presence in the area. The miombo contains some of the largest large mammal populations left in Africa, with large herbivores including elephant, rhino, buffalo and many species of antelope. Typically, these species need to undertake seasonal movements as the region has extended dry seasons and animals often need to move around to find food and water. There are also numerous species of endemic animal and plant species across the huge extent of the region, although the density of endemic species is low in this region as most species have large ranges.

Trends and future dynamics: Savannas are in a state of decline in most of East Africa and adjacent islands. Corridors for migratory animals have been reduced mostly through human settlement and farming. Populations of ungulates have declined at high rates where bush meat is a major source of protein. Black rhinoceroses have been decimated by trophy hunters and poachers for their horns. Plant species, such as the African Blackwood (*Dalbergia melanoxylon,* Lower Risk/near threatened), are threatened by overharvesting because of their commercial value in making carvings for tourists and furniture (WWF, 2017b).

3.4.3.1.4. Dryland and desert

Status: About 80% of the east African region's total area consists of sparse herbaceous/grassy steppe (e.g., *Acacia tortilis*) (Ludwig *et al.*, 2004), and the stands of mangroves (e.g., *Rhizophora mucronata*, Least Concern) in the southern part of the Red Sea Coastal desert, and spiny bush in the south and west of Madagascar Spiny Thickets (124,060 km^2) (Phillipson, 1996) Somali montane xeric woodlands (62,159 km^2 and the Somali and Eritrean coastal deserts (30,300 km^2) (WWF, 2017a). The xeric woodlands of Madagascar are critically endangered, the Somali desert ecosystems are vulnerable and the Somali xeric woodlands are also critically endangered. However, the Eritrean coastal desert is relatively stable (WWF, 2017a). The majority of these zones are recognised as important zones of endemism. For example, an estimated 825 to 950 plant species have been observed in Danakil depression and its surrounding, with 25 species endemic to this region and the adjacent equally dry parts of Ethiopia and Somalia (Friis *et al.*, 2001), and several hundred endemics to Somali Montane Xeric Woodlands (Friis, 1992; Thulin, 1994; WWF *et al*., 1994; Lovett *et al*., 1996). The highest percentage of plant endemism has been observed in Madagascar (Phillipson, 1996). Some of the endemic plants are extremely rare and have highly restricted ranges, such as *Aloe suzannae* (Liliaceae) and the palm, *Dypsis decaryi* (Vulnerable), as well as tiny *Euphorbia* herbs, *Pachypodium* spp., and *Hibiscus* shrubs.

The overall number of reptiles is relatively low, with strict endemics limited to roughly three species in Eritrean Coastal Desert (Ogaden burrowing asp (*Atractaspis leucomelas*), Ragazzi's cylindrical skink (*Chalcides ragazzii*), and Indian leaf-toed gecko (*Hemidactylus flaviviridis*)), and three other endemic reptiles in Somali Montane Xeric Woodlands (*Spalerosophis josephscorteccii* and *Leptotyphlops reticulatus,* and the lizard (*Pseuderemias savage*)) (Stattersfield *et al.*,1998). In all vertebrates levels of endemism are low, for example there only occurs only one Archer's lark (*Heteromirafra archeri*, Critically Endangered), a rodent, *Gerbillus acticola*, and two geckos, Arnold's leaf-toed gecko (*Hemidactylus arnoldi*) and a subspecies of the northern sand gecko (*Tropiocolotes tripolitanus somalicus*, Least Concern) in Ethiopian xeric grasslands and shrublands.

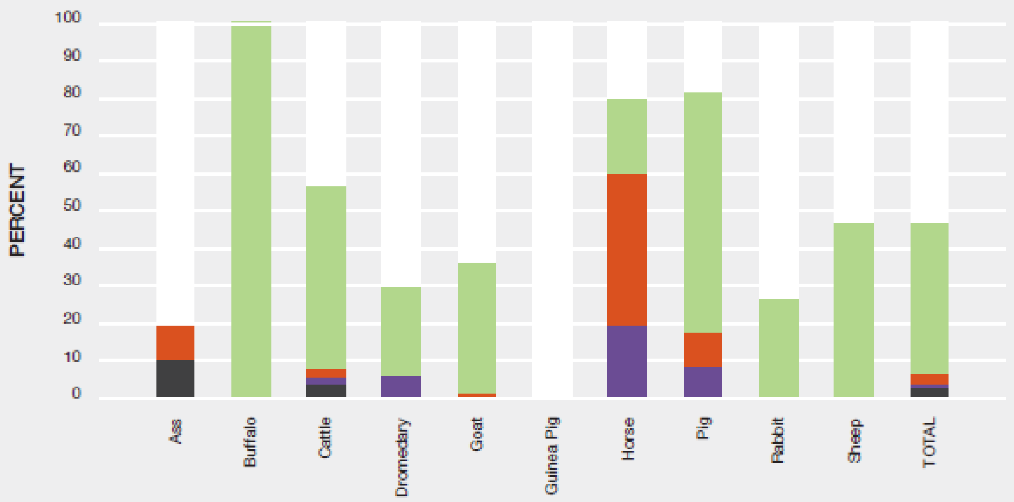
Among the mammals, desert ungulates are well presented. For example, Dorcas gazelle (*Gazella dorcas*, Vulnerable), Sömmerring's gazelle (*Gazella soemmerringii*, Vulnerable) and Salt's dikdik (*Madoqua saltiana,* Least Concern) are well known (Hilton-Taylor, 2000) in most part of desert, with the white-footed sportive lemur (*Lepilemur leucopus,* Endangered), Grandidier's mongoose (*Galidictis grandidieri*, Endangered), and grey mouse lemur (*Microcebus murinus,* Least Concern). With near-endemic mammals such as, the large-eared tenrec (*Geogale aurita*, Least Concern), and the lesser hedgehog tenrec (*Echinops telfairi*) only found in Madagascar (WWF, 2017a).

Trends and future dynamics: Drylands and deserts in East Africa and adjacent islands are largely intact but degraded by overgrazing and fuel collection, particularly near settlements. One of the major threats is over-exploitation of useful species e.g., *Hazomalania voyroni* (Least Concern) which has been over-harvested in Madagascar for construction wood although attempts are being made at replanting the species (Randrianasolo *et al.*, 1996). With current absence of protected areas, and weak environmental law enforcement, flora and fauna in these deserts is likely to be adversely affected.

3.4.3.1.5. Cultivated lands

Status and trends: Among the estimated 7,500 plant species in East African region (specifically in Kenya) are important wild species of vegetables, fruits, forage grasses, legumes, browse plants, cereals, pulses, oil crops, forest species, medicinal plants; which account for about 75% of agricultural production and over 75% of income generation (Salami *et al.*, 2010). No study exists on the level of genetic erosion of farmed species that has taken place in East Africa and adjacent islands (FAO, 2009a). However, it is believed in the last decade a lot of diversity has been lost due to both biotic and abiotic factors, despite the efforts being made in germplasm conservation. These factors include: aggressive promotion of exotic vegetables; changes in eating habits and over-exploitation; population pressure on land and changes in land (FAO, 2009a). Of the 291 known species of mammalian and avian breeds in East Africa, 12 are categorised as at risk. However, this is probably an underestimate of the actual situation, primarily due to a lack of information (FAO, 2007c; Figure 3.11 & 3.12).

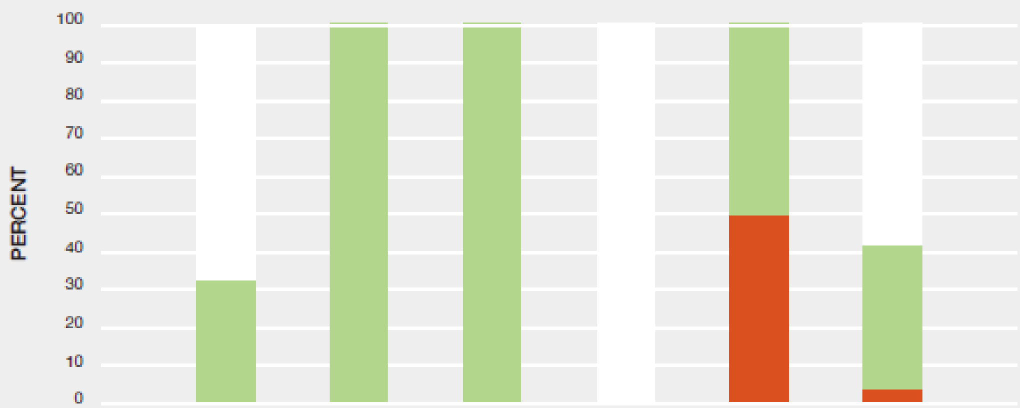
Future dynamics: Similar to other subregions, the plant genetic diversity used in agriculture–crops and livestock breeds is predicted to erode further is no interventions are taken.



RISK STATUS	Ass	Buffalo	Cattle	Dromedary	Goat	Guinea Pig	Horse	Pig	Rabbit	Sheep	TOTAL
Extinct	1	0	4	0	0	0	0	0	0	0	5
Critical	0	0	1	1	0	0	1	1	0	0	4
Endangered	1	0	2	0	1	0	2	1	0	0	7
Not at risk	0	1	47	4	19	0	1	7	3	25	107
Unknown	8	0	41	12	35	2	1	2	8	28	137
TOTAL	10	1	95	17	55	2	5	11	11	53	260

* Breeds that are also recorded in countries outside Africa are excluded from the analysis.

Figure 3.11: Risk status of livestock breeds recorded in East Africa* as of December 2005: absolute (table) and relative (chart) figures. Source: FAO (2007c).



RISK STATUS		Chicken	Duck	Goose	Guinea fowl	Turkey	TOTAL
Endangered		0	0	2	0	1	7
Not at risk		8	1	2	4	1	12
Unknown		17	0	0	1	0	18
TOTAL		25	1	2	1	2	31

* Breeds that are also recorded in countries outside Africa are excluded from the analysis.

Figure 3.12: Risk status of avian domestic breeds recorded in East Africa* up to December 2005: absolute (table) and relative (chart) figures. Source: FAO (2007c).

3.4.3.2. Aquatic (Freshwater, Marine and Coastal)

3.4.3.2.1. Wetlands and mangroves

Status: Wetlands and mangroves in East Africa and adjacent islands account for 80% of the total wetland area (Kalinga *et al.*, 1998; Spalding *et al.*, 2010). The largest mangrove areas are in one of global biodiversity hotspot-Madagascar (2,991 km^2) and Mozambique (2,909 km^2) (Chapman *et al.*, 2001; Samoilys *et al.*, 2015). However, the Rufiji Delta contains the largest continuous block of estuarine mangrove forest in East Africa and adjacent islands. The major wetlands in East Africa and adjacent islands include the major lakes Tanganyika, Nyasa, Turkana and Victoria; the small lakes Rukwa, Manyara, Eyasi, Natron, Kitangiri, Burigi, Ikimba (Samoilys *et al.*, 2015). Lake Turkana has more than 350 species of aquatic and terrestrial birds, and is also an important flyway for migrant birds, including more than 100,000 little stint (*Calidris minuta*, Least Concern) (Bennun *et al.*, 1999). Central Island has a breeding population of African skimmers (*Rynchops flavirostris*, Near Threatened). Mangroves in East Africa are a home of 10 species, the most common species being *Avicennia marina* (Least Concern), *Rhizophora mucronata* (Least Concern), and *Ceriops tagal* (Least Concern). The only endemic mangrove is *C. somaliensis*, found only in Somalia. Salt *Avicennia* and *Sonneratia* leaves from mangroves are important sources of food feed for the Zebu cattle (Cormier-Salem, 2007).

Mangroves forests and wetlands provide fertile land for agriculture which contributes to the livelihood of rural communities. They are key breeding sites for marine fisheries. Concerns have been raised over the increasing erosion of wetlands and mangrove forest fauna and flora due to water and soil pollution (Beuel *et al.*, 2016). For instance, recent studies have revealed severe degradation of crabs and molluscs due to polluted waters and soils of the wetlands and mangrove forest. Since 2011, non-governmental organisations have been involved in projects in Madagascar to assess the feasibility of using payments for blue carbon as a long-term financial mechanism for community-based mangrove management (Leach *et al.*, 2013; Cormier-Salem *et al.*, 2016).

Trends and future dynamics: Mangroves in the Kilifi area in Kenya only make up a small proportion of the total area, but have seen the highest rate of loss estimated at 18% between 1985 and 2010 (Kirui *et al.*, 2013). In Madagascar, the loss of mangroves was found to be 7% of mangrove forests from 1975 to 2005 (Giri *et al*., 2008). Mangroves are particularly overexploited in the areas surrounding major cities on the East African coast, such as Mombasa, Dar-es-Salaam and Maputo, becoming heavily degraded or destroyed by multiple pressures on resources and pollution. Domestic wastewater has for instance detectable effects on crabs and molluscs, suggesting their usefulness as bioindicators of its effects in mangroves. They are also threatened by erosion caused by tree-cutting in the highlands, and by land grabbing. Due scarcity of wood from other hinterland sources, direct harvesting of the mangrove trees is occurring. Demographic trends suggest this situation could change in the future (Spalding *et al.*, 1997).

With current: lack of protected areas in desert areas; lack of enforcement; expansion of the Rift valley in Ethiopia; overgrazing, and increasing permanent settlements, some species endemic to wetlands and mangrove forest in East Africa are likely to face extinction. A further potential threat is continued climate change.

3.4.3.2.2. Inland surface waters and water bodies/freshwater

Status: There are 12 main river basins that flow into Western Indian Ocean (WIO) of which 6 are in Kenya, Tanzania and Mozambique (UNEP, 2009). These rivers support extensive mangrove forests often associated with seagrass beds (Samoilys *et al.*, 2015), and provide important bursary grounds and breeding areas for numerous commercially important fishery species such as tuna and mackerel (e.g., *Scomberomorus commerson*, Near Threatened). Eastern Africa, an area rich in freshwater species and very high levels of endemism, has just fewer than 26% of species assessed as regionally threatened (Darwall *et al.*, 2005). They host several commercially important fish species such as Nile Perch (*Lates niloticus*) and tilapia (*Oreochromis niloticus*, *O. leucosticus* and *Tilapia zillii* (Least Concern)) (Bwathondi, 1990). Many migratory bird populations rely on these river deltas as well as on wetlands and mangrove forests as a winter stopover (Samoilys *et al.*, 2015). An estimated 40,000 water birds comprising 62 species inhabit the Rufiji Delta (Spalding *et al.*, 2010).

Trends and future dynamics: The major rivers in East Africa have been dammed to varying extents for hydropower, water supply or irrigation. This has to a certain extent together with mangrove harvesting and removal affected the diversity of flora and fauna in inland waters adversely. In addition to dams construction, alien invasive species, desertification, agricultural encroachment, overexploitation and pollution are some of the leading causes of freshwater species decline and ecosystem degradation (Revenga *et al.*, 2003). Even though some of these areas are protected, management of these sites do not effectively combat these threats. A particular concern is the potential impact of water resource development such as construction of dams for water supply, irrigation and hydro-electricity on freshwater biodiversity. To help ensure the conservation of these water bodies, biodiversity information should be integrated with environmental and development planning and identification of Key Biodiversity Areas for inland waters of Eastern Africa.

3.4.3.2.3. Shelf ecosystem

Status: The shelf ecosystems of East Africa and adjacent islands commonly known as the Eastern African Marine Ecoregion (EAME) harbour a characteristic set of species, habitat, dynamics and environmental conditions (Wells *et al.*, 2007). Since the first marine protected areas were established in the 1960s and 1970s, 8.7% of the continental shelf in Kenya, 8.1% in Tanzania and 4.0% in

Mozambique has been designated (Wells *et al.*, 2007). The coast consists of lagoons, coastal lakes, mangrove forests, inshore reefs and other habitat types (Wells *et al.*, 2007). EAME support an incredibly rich species composition, exceeding 11,000 species of plants and animals (e.g., *Dugong dugon*, Vulnerable) (WWF, 2017a). In a rare occurrence, 10 dugongs were sighted in the seagrass beds next to the Rufiji Delta (Sea Sense, 2011). The region has a highly diverse fish fauna (over 1,500 species of fish are recorded). One of the most notable fish in the region is the coelacanth (*Latimeria chalumnae,* Critically Endangered) (Wells *et al.*, 2007).

There are also significant populations of corals (200 species), seagrass (12 species), marine algae (1,500 species), several hundred sponge species, molluscs (3,000 species), crabs (450 species), with about 10-15% of species considered to be endemic to the region. Certain parts of the shore areas provide feeding and breeding areas for a high diversity of resident and migratory birds and marine turtles such as the olive ridley (*Lepidochelys olivacea*, Vulnerable), green turtle (*Chelonia mydas*, Endangered) and hawksbill (*Eretmochelys imbricate*) (Wells *et al.*, 2007), all of which are CITES listed. The open waters are important for many species of pelagic fish including the Black marlin whose distribution is restricted to Eastern Africa and Australia and many increasingly endangered elasmobranchs such as the Whale shark, Great White shark, sawfish and manta ray.

<u>Trends and future dynamics:</u> Increasing demands for marine resources have resulted in significant ecological changes in many parts of EAME, largely due to destructive fishing, notable blast fishing and water pollution (Cinner *et al.*, 2015). Continuation of some of these activities coupled with temperature-induced coral bleaching (Veron *et al.*, 2009) is likely to result in complete loss of biological diversity of EAME. Of particular concern if the loss of coralline algae, which is essential for cementing coral rubble into solid reef–a critical habitat for many organisms (Veron *et al.*, 2009). Therefore proper management of Shelf ecosystem if of immerse importance for improving the chances of achieving social-ecological sustainability (see Cinner *et al*., 2015).

3.4.3.2.4. Open Ocean

<u>Status and trends:</u> Coastal fish diversity is relatively high in East Africa and adjacent islands, with approximately 1,000 species identified and 142 endemics (Briggs *et al.*, 2012). Marine crustacean biodiversity is poorly documented, however, 165 species of shrimp have been identified in Seychelles, many of which are endemic. There are also a number of regionally endemic crustacean species associated with coral habitats (Briggs *et al.*, 2012). Marine catches are around 550,000 tons in 2014 for overall catches compared to less than 1 million tons for continental catches (especially from Lake Victoria). Major species are small pelagic, caught almost everywhere along the coast and demersal fish, essentially caught by artisanal fishermen. Most of the coastal stocks are fully exploited or overexploited (FAO, 2016).

3.4.3.2.5. Deep sea

<u>Status:</u> The fauna inhabiting seamounts found in West Indian Ocean is poorly known (Rogers, 2012). More studies have been undertaken on Walter's Shoal (submerged mountains off coast of Madagascar) due to its proximity to the land (Rogers, 2012). Species found at shallow waters of Walter's Shoal include *Comanthus wahlbergi tenuibrachia* (Collette *et al.*, 1991) and several crustaceans including an endemic species of aphid shrimp (*Alpheus waltervadi*) and endemic isopod (*Jaeropsis waltervadi*). Whilst little is known about the diversity of deep seas in Indian Ocean, recent studies have discovered an endemic species of rock lobster (*Palinurus barbarae*) (Groeneveld *et al.*, 2006), and West Indian Ocean coelacanth *Latimeria chalumnae* (Critically Endangered) (Nulens *et al.*, 2011). Deeper depths

(~400 metres) of Walter's Shoal hosts over 50 species of fishes, which several are endemic (Shotton, 2006). Water birds are very rare and scarce (Shotton, 2006). The most commonly found bird species around areas of deep-water fishing are white-chinned petrels (*Procellaria aequinoctialis*, Vulnerable), cape petrels (*Daption capense*, Least Concern), and sooty shearwaters (*Puffinus griseus*, Near Threatened) (Shotton, 2006).

Trends and future dynamics: The fisheries of the Indian Ocean are subject to multiple stressors including: fishing, ocean acidification, changing sea temperatures, salinity and dissolved oxygen. Therefore, there is an urgent need for enforcement of (a) the Southwest Indian Ocean Fisheries Commission, which was opened in 2004 to promote sustainable utilization of marine living resources, and (b) the South Indian Ocean Fisheries Agreement (Rogers, 2012).

3.4.4. West Africa

3.4.4.1. Terrestrial

3.4.4.1.1. Tropical and subtropical dry and humid forest

Status: West African rainforests (12,002 million hectares) account for about 6% of African rainforests (Mayaux *et al.*, 2013; Figure 3.13). The Guinean forests of West Africa are recognised as a biodiversity hotspot with high levels of biodiversity (e.g., primate diversity) and endemism. Mammal diversity is exceptional. For example, an estimated 390 terrestrial mammal species (16% threatened) are found in Guinea forests, representing over one-quarter of roughly 1,100 total African mammal fauna that are native to continental Africa represented (CEPF, 2015). More than 60 mammals are endemic to these forests (e.g., two rarest antelopes in the world: the Endangered Jentink's duiker and the Vulnerable zebra duiker) (CEPF, 2015). West African rainforests are home to 917 species of birds (5% are threatened), of which 48 are endemic and more than 9,000 vascular plant species, of which around 20% are thought to be endemic (Brooks *et al.*, 2000; Mittermeier *et al.*, 2004). The diversity of amphibians (29% are threatened) and reptiles (10% are threatened) species is poorly documented, although it is suggested that more than 200 species of amphibians and reptiles recorded (Bakarr *et al.*, 2004; Norris *et al.*, 2010; Mallon *et al.*, 2015) and more likely to be discovered in future. The total carbon stock in West African rainforests is estimated at 5.8 GT, corresponding to 11.6% of the total carbon storage in Africa (Mayaux *et al.*, 2013).

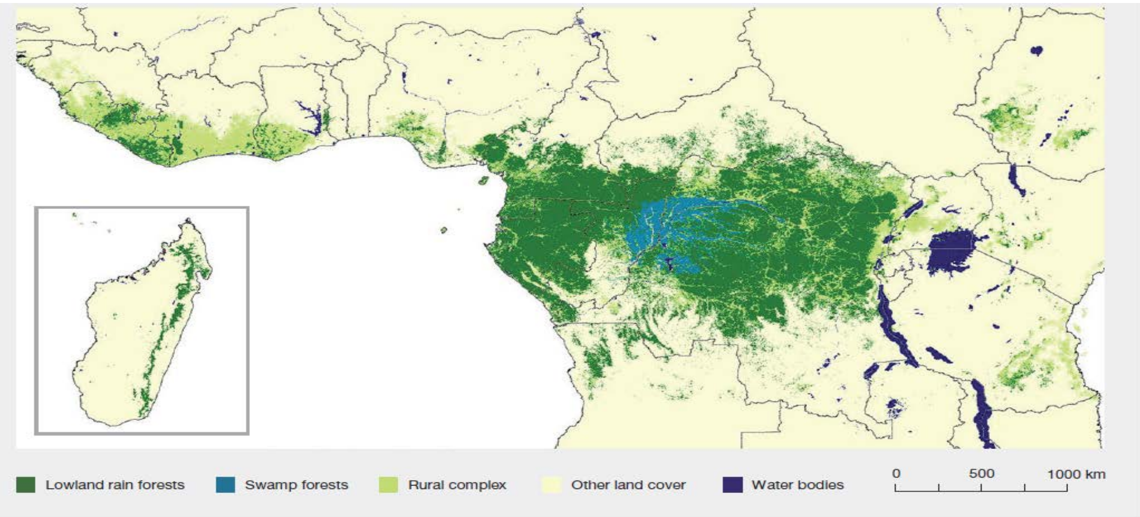


Figure 3.13: Spatial distribution of the rainforests in West Africa. Source: Mayaux *et al.* (2013).

The dry forest areas in West Africa are located in the Cape Verde Islands, with an extent of approximately 4,661 km^2 (WWF, 2017d). Four species of land-birds are endemic to these islands (Bourne, 1955; Stattersfield *et al.*, 1998), and 12 of the 15 species of lizards on Cape Verde are endemic (Stuart *et al.*, 1990). These regions support breeding populations of three bird species, Fea's petrel (*Pterodroma feae*, Near Threatened), magnificent frigate bird (*Fregata magnificens*, Least Concern) and red-tailed tropicbird (*Phaethon rubricauda*, Least Concern) (BirdLife International, 2000; WWF, 2017d).

Trends: The region lost 80% of its original forest cover by 1980s affecting not only the habitats of animals (e.g., great apes (MacKinnon *et al.*, 2015)), but also the rainfall. During the last decades precipitation has diminished (Campbell, 1996; Campbell *et al.*, 2000). Annual deforestation rate in West African rainforests for the period of 2000–2010 is estimated to be 0.35% (Mayaux *et al.*, 2013; Figure 3.14). The native vegetation in the dry forest of the Cape Verde Islands has been declining and is now severely fragmented (WWF, 2017d).

In recent years, harvesting of amphibians, vultures and iconic species in West Africa for international trade, food, medicine and cultural purposes has intensified markedly (Mohneke *et al.*, 2009, 2010; Onadeko *et al.*, 2011; Botha *et al.*, 2012). Of 49 important amphibian species, 92% are for the pet trade (Carr *et al.*, 2014). A total of 450,000–2,738,610 frogs are harvested annually in West Africa (Mohneke *et al.*, 2011). Not only amphibians are severely declining, so are the populations of *Panthera leo*. In 2002 the population of *Panthera leo* was estimated to be 1,230 (Chardonnet, 2004), 835 in 2004 (Bauer *et al.*, 2004) and 406 in 2014 (Henschel *et al.*, 2014). Recent surveys also suggest that the African elephant, and African wild dogs have disappeared from much of their formers range in West Africa, with small and isolated population of lion only found in three protected areas (Chase *et al.*, 2011). More than 90% of elephant population in West Africa has been lost in the 20th century (MacKinnon *et al.*, 2015). The remaining isolated and small populations consist of little more than 100 elephants (MacKinnon *et al.*, 2015). Severe declines of large birds have also been reported in West Africa (Thiollay, 2001; Rondeau *et al.*, 2004; Thiollay, 2006a, b, & c), with collapse of raptor populations in protected areas (Thiollay, 2007).

Future dynamics: With projected climate change (Belle *et al.*, 2016), ongoing overhunting and conversion of forest to agriculture (FAO, 2015b); forest species (in particular mammals, amphibians, reptiles, and birds) and their services are expected to be negatively impacted in West Africa. For example, 91% of the amphibian, 40% of bird, and 50% of mammal species are projected to be found in areas of lower climate suitability by the 2070–2099 time period (Belle *et al.*, 2016). It is therefore crucial to consider conservation of this taxonomic groups, specifically for those species that have been assessed globally as threatened (Belle *et al.*, 2016).

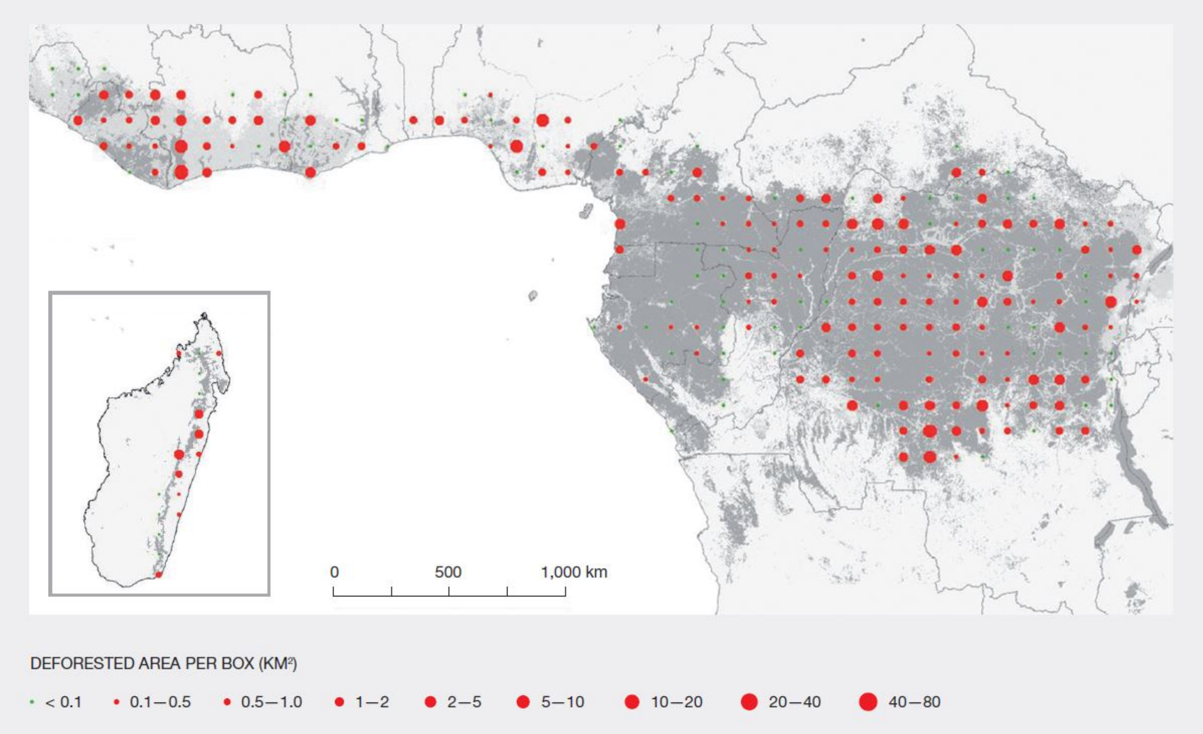


Figure 3.14: Net deforestation between 1990 and 2000. The circle size is proportional to the surface affected by deforestation in each sample of 100 km^2. Source: Mayaux *et al.* (2013).

3.4.4.1.2. High mountain habitats

Status: The Guinean Montane Forest ecoregion consists of scattered mountains and high plateau areas. Parts of the ecoregion are found in four West African countries, from Guinea in the west to Côte d'Ivoire in the east (Morton, 1986). Bintumani Peak on Loma Mountain (1,947 metres) in Sierra Leone is the highest peak in Africa west of Mount Cameroon (Cole, 1968). Tingi Hills, and Sankabiaiwa, also in Sierra Leone, both attain a height of 1860 metres. Other notable mountains in this ecoregion are Mount Nimba (1,752 metres) (Curry-Lindahl, 1966), the Simandou Massif in Guinea (1,650 metres), the Ziama Massif (1,387 metres) in Guinea, Mount Dutova in Liberia, and the Man Massif and Mont Peko in Côte d'Ivoire. Average rainfall is between 1,600–2,400 millimetres/year (Morton, 1986), and most major rivers in West Africa have their origins within the peaks of the Guinean Montane Forest ecoregion. For example, the most westerly tributary of the Niger River originates in the Loma Mountains of Sierra Leone, while the Senegal and Gambia Rivers originate in the Fouta Djallon of Guinea. The Sewa River in Sierra Leone has many of its tributaries arising from the Loma Mountains and Tingi Hills, making it the most important watershed in the country. There is considerable variation in the rainfall on different sides of the mountains. Temperatures are also quite extreme on these mountain slopes, with maximum temperatures ranging between 24ºC and 33ºC while minimum temperatures can fall below 10ºC. White (1983) classified the forests here as part of an Afromontane archipelago-like regional centre of endemism. Lowland forest, part of the greater Guinea-Congolian forest complex, occurs on the lower reaches of the mountains closer to the coast. On northern slopes, forest-savanna mosaic becomes montane forest with increasing elevation and precipitation. At mid-altitudes (above 1,000 metres), the forest is often shrouded in clouds, resulting in verdant growth of epiphytes. With increasing altitude on the highest mountains, forests give way to grassland intermixed with bamboo, wetlands and gallery forests. The dominant flora of the grassland includes the genera *Anadelphia*, *Loudetia*, and *Tristachya* (Morton, 1986). Grassland also occurs on the ridges and peaks of Mount Nimba and is generally dominated by Andropogon and Loudettia, while the sedge, *Hypolytrum cacuminum* (Endangered) occurs on some wetter slopes (Morton, 1986).

According to Cole (1968), 4 plant communities have been recognised on these massifs, including closed forests and Guinea savanna (460–915 metres), sub-montane shrub savanna (915–1,700 metres), montane grassland (prairie d'altitude) (1,700 metres) and sub-montane gallery forests (1,700 metres). At higher altitudes, the shrub layer of the sub-montane shrub savanna of the Loma Mountains and Tingi Hills is comprised of *Syzygium* spp., *Kotschya ochreata* var *ochreata*, *Monechma depauperatum*, *Dissotis elliotii*, *Dissotis fructicosa* and the tree ferns, *Cyathea manniana* and *Cyathea dregei*. Tree ferns are noted as common in the gallery forest (Cole, 1968; Morton, 1986).

The diversity and endemism on Mount Nimba is well documented, with over 2,000 species of vascular plants recorded (WWF *et al*., 1994). Biodiversity studies of the Loma Mountains have produced considerable information about the flora, with records for 1,576 species distributed in 757 genera and 135 families (WWF *et al*., 1994). Nine species are endemic to Loma mountains, and include *Afrotrilepis jaegeri*, *Digitaria phaeotricha* var. patens, *Dissotis sessilis*, *Gladiolus leonensis*, *Ledermanniella jaegeri*, *Loudetia jaegeriana*, *Loxodera strigosa*, *Schizachyrium minutum* (*S. brevifolium*) and *Scleria monticola* (Jaeger, 1983). The four endemic plant families found in tropical Africa are also represented in the Loma Mountains by *Triphyophyllum peltatum* (Dioncophyllaceae), *Octoknema borealis* (Octoknemataceae), *Bersama abyssinica* (Melianthaceae), and *Napoleona leonensis* and *Napoleona vogelii* (Lecythidaceae). For the entire Guinean Montane Forest (including the following mountains: Fouta Djalon, Loma, Tingi, Nimba and Man), 35 endemic plants including 11 palaeo-endemics have been recorded (Schnell, 1952; Cole, 1967; Morton, 1972; Cole, 1974; Jaeger *et al*., 1975). The 11 palaeo-endemics are *Borreria macrantha*, *Cyanotis lourensis*, *Droogmansia scaettaiana* (Near Threatened), *Eriosema parviflorum*, *Eugenia pobeguinii*, *Hypolytrum cacuminum* (Endangered), *Kotschya lutea*, *Mesanthemum aurantum*, *Rhytachne glabra* (Vulnerable), *Vernonia nimbaensis* and *Xyris festucifolia* (Cole, 1974). A total of 101 species in the Orchidaceae have been recorded for Mount Nimba, including one endemic species *Rhipidoglossum paucifolium* (Johansson, 1974). Phorophytes like *Heritiera utilis* (Vulnerable), *Lophira alata* (Vulnerable) and *Parinari excelsa* (Least Concern) were also reported to carry an abundance of epiphytes. There are Mount Nimba otter shrew (*Micropotamogale lamottei*, Near Threatened) (Hilton-Taylor, 2000), two species of white-toothed shrew (*Crocidura obscurior,* Least Concern and *C. nimbae*, Near Threatened) and a species of leaf-nosed bat (*Hipposideros marisae*, Vulnerable). A number of other rare forest mammals may also occur marginally in the mountains of this ecoregion, including Johnson's genet (*Genetta johnstoni*, Near Threatened) and a murid rat (*Praomys rostratus*, Least Concern). The western chimpanzee (*Pan troglodytes* verus, Endangered) also occurs in this ecoregion, with high densities reported from Mt Loma. The largest predator in the ecoregion is the leopard (*Panthera pardus*, Vulnerable). The avifauna of Mount Nimba has been well described and includes the near-endemic Sierra Leone prinia, the grey-winged robin-chat (*Cossypha polioptera*, Least Concern) and lemon dove (*Columba larvata*, Least Concern), and Sharp's apalis (*Apalis sharpii*, Least Concern) (Colston *et al.*, 1986; Gatter, 1997). The presence of the rare yellow-headed rock fowl (*Picathartes gymnocephalus*, Vulnerable) has also been confirmed in the Loma Mountains (Thompson, 1993). The ecoregion is also of importance for endemic amphibians. More than 10 species are believed to be strictly endemic (WWF *et al*., 1994), including *Nimbaphrynoides occidentalis* (Critically Endangered), an endemic toad occurring in savannas on Mount Nimba (Curry-Lindahl, 1966). Several new species of insects in the family Coleoptera have been reported for both the Loma and the Nimba Mountains (Villiers, 1965). For the Loma Mountains, these include *Promecolanguria lomensis*, *Barbaropus bintumanensis* and *Barbaropus explanatus*. The species recorded on Mount Nimba include *Promecolanguria dimidiata*, *Promecolanguria pseudosulcicollis*, *Promecolanguria mimbana*, *Promecolanguria armata* and *Barbaropus nigritus*.

Trends: The Upper Guinea Forest receives less annual rainfall and has higher rainfall seasonality than pan-tropical rainforests, which are characterized by annual rainfall greater than 1,500 millimetres with little-to-no dry season (Peel *et al.*, 2007; Malhi *et al.*, 2009). Since the 1970s, a drying trend has been observed, and these changes have been primarily associated with shifts in a natural low-frequency mode (65–80 years) of sea surface temperature (Hulme *et al.*, 2001). Rapid population growth has exacerbated regional development pressures, including timber harvesting and demand for agricultural land (Knauer *et al.*, 2014). Vegetation analysis indicated that declines in woody coverage were the predominant trends across the Upper Guinea Forest region of West Africa, even in the drier Guinean Forest Savanna Mosaic and West Sudanian Savanna ecoregions that were also characterized by widespread trends of increasing greenness as measured by environmental vegetation index (Liu *et al.*, 2017). Such a decline in woody vegetation was also captured between 1990 and 2000 along the West African forest-savanna transition zone (Bodart *et al.*, 2013). Recent landscape-level studies of land cover and land-use change in the forested zone of southwestern Ghana have also documented declining trends in woody vegetation cover, with the largest decreases occurring near the forest-savanna boundary (Alo *et al.*, 2008; Dwomoh *et al.*, 2017). Despite the widespread decline of woody vegetation in many of the drier parts of West Africa, remotely-sensed greenness metrics also indicated a prevalence of greening, consistent with re-greening trends found in many other studies of West Africa (Herrmann *et al.*, 2005; Brandt *et al.*, 2015; Kaptué *et al.*, 2015).

3.4.4.1.3. Savannah and grassland

Status: The savannahs and grasslands of West Africa are rich in biodiversity. The West African savannah occupies about 60% of the surface of tropical Africa, with its appearance and degradation status largely determined by human activities (Laube, 2007). The grass component of the northern dunes is dominated by *Cenchrus biflorus*, *Aristida mutabilis* and *Schoenfeldia gracilis*. Grasslands like *Echinochloa stagnina*, *Oryza barthii* (Least Concern) and *Vossia cuspidata* provide excellent grazing when the floods have receded. These areas were historically rich in wildlife including megafauna such as elephant, giraffes, lions, cheetahs and many ungulates. However, today the faunal diversity of the savannahs and grasslands are restricted to isolated pockets of protected areas that are facing large pressures from encroaching human populations.

Trend: The Sahelian grazing lands have suffered much damage in the past 50 years, through an increasing human population, excessive advance of cropping into very marginal areas and serious deforestation, mainly for firewood, all exacerbated by recurrent droughts. *Andropogon gayanus* is becoming scarce because of clearing and in cultivated areas has been replaced by vast areas of poor, unpalatable grasses. The 2017 IUCN Red List Animals listed Scimitar-horned Oryx (*Oryx dammah*, Extinct in the Wild) as extinct in Burkina Faso, Mali, and Niger. The 2004 IUCN Red List Animals listed *Gazelle dorcas* in Mauritania as Endangered, Mali as Probably Endangered, Niger Probably Vulnerable or Endangered, Senegal as Extinction in the wild Burkina Faso as Probably Endangered and Nigeria as Possibly Extinct.

3.4.4.1.4. Dryland and desert

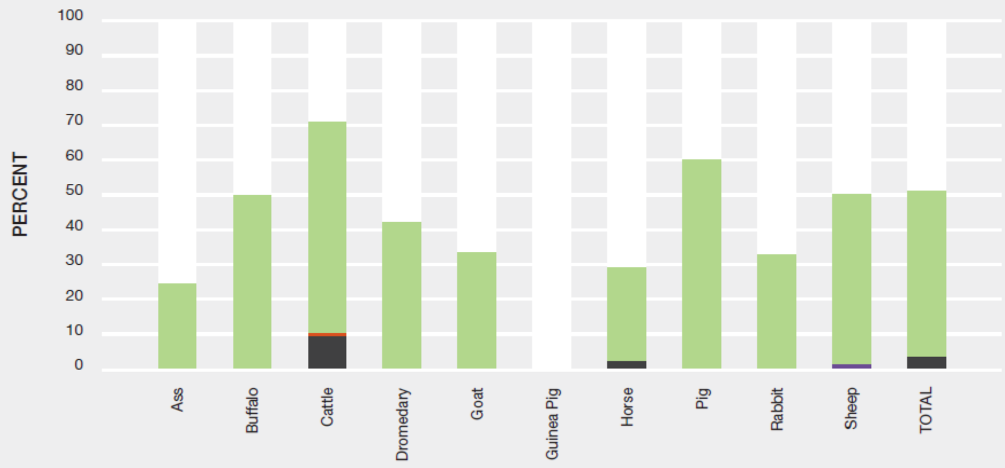
Status and trends: Western African countries with substantial covers of aridity zones include; Chad, Mali, Mauritania and Niger. Countries with some semi-arid and dry sub-humid arid cover include Benin, Gambia, Ghana, Nigeria and Senegal. In West Africa only Gambia had a net forest cover gain of 1.0% during the decade. (Bellefontaine *et al.*, 2000; FAO, 2001b). Rainfall decreases from south to north, so the vegetation belts run east-west. The average Sahelian rainfall is of 250–500 millimetres with dry season of nine to eleven months. According to Wickens (1997), the 150 millimetres isohyet corresponds to the southern limit of the Saharan species *Cornulaca monacantha, Panicum turgidum* and *Stipagrostis pungens* and to the northern limits of such Sahelian shrubs as *Boscia senegalensis* and *Commiphora africana* and the grass *Cenchrus biflorus* in the northern Sahel. The Sahel's southern limit adjoins the deciduous woodlands of the Sudanian domain at between 450 and 500 millimetres/year of precipitation. *Acacia* spp. dominate the thin scrub along with *Balanites aegyptiaca*; laterite outcrops and cuirasses are colonized by *Combretum nigricans*, *Guiera senegalensis*, *Lannea acida* and *Sclerocarya birrea*. The Saharan cheetah (northwest African cheetah) lives in Niger, Mali, Benin, and Burkina Faso. There are also small desert crocodiles at Mauritania. *Oryx dammah* (Extinct in the Wild) are constituted by the Sahelian populations found in Niger and in Mali (Grettenberger *et al.*, 1990). During the 1970's, the Oryx seems to have been reduced to small groups (Dragesco-Joffé, 1993) living on the desert edges of Niger between Agadez and the Termit (Grettenberger *et al.*, 1990). The Scimitar-horned Oryx is extinct in the wild and has been reintroduced in large fences within a protected area in Senegal (CEPF, 2015). The species was present in the area from the Louga region in the west to the Bakel region in the east (White, 1983; Sournia *et al.*, 1990). The Scimitar horned Oryx is now in the south-Sahelian deciduous shrub zone in Burkina Faso (White, 1983) and in the south-Sahelian deciduous shrub belt in Nigeria (White, 1983; Anadu *et al.*, 1990).

3.4.4.1.5. Cultivated lands

<u>Status and trends:</u> West Africa is composed of an array of diverse ecosystems and an equally high number of food production systems (Cotillon, 2017). West African agriculture contains a rich variety of economically important resources. These resources include (i) cash crops like cotton, coffee, cacao, groundnut, palm, and cashew, millet, sorghum, maize, paddy rice, and (ii) animals like cows, sheep, pigs, and poultry. In West Africa, a total of 266 crop wild relatives have been identified and among the 20 of 266 appeared to be species demanding highest priority for conservation (Idohou *et al.*, 2013). The number of the income crops that have declined or disappeared in Western Africa is striking. Of the 530 known species of mammalian and avian breeds in North and West Africa, 18 are categorised as at risk. However, this is probably an underestimate of the actual situation, primarily due to a lack of information (FAO, 2007b; Figure 3.15 & 3.16).

There have been three main causes of these major crop declines; pests and disease pressures (Chapter 4, section 4.2.1.3; Table 4.2), changes in market or consumption preferences, and least significant, fertility decline or land shortage (Goldman, 1995). The same problems also face livestock populations, particularly the indigenous Zebu cattle breeds in Nigeria, which are reported to have been badly affected by corridor disease (a tick-borne disease) during the last ten years (FAO, 2007b). Other driving forces of livestock diversity erosion include climate change, drought, quantitative and qualitative changes in demand for livestock products and services (FAO, 2007b).

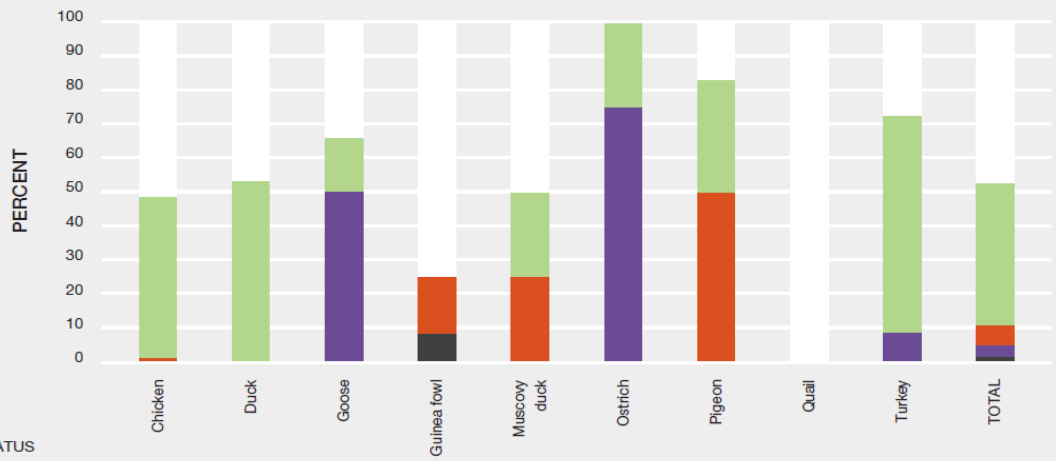
More than anywhere else, West Africa is a home to a diversity of agro-ecosystems (Figure 3.17). These ecosystems create a strong production base for a range of crops and encourage complementarity between major production areas. The forest areas with the sub-tropical climate are excellent for production of roots (cassava) and tubers (yams) making West Africa one of the world's major repositories of these crops (Reynolds *et al.*, 2015).



RISK STATUS	Ass	Buffalo	Cattle	Dromedary	Goat	Guinea Pig	Horse	Pig	Rabbit	Sheep	TOTAL
Extinct	0	0	11	0	0	0	1	0	0	0	12
Critical	0	0	0	0	0	0	0	0	0	1	1
Endangered	0	0	1	0	1	0	0	0	0	0	1
Not at risk	3	1	70	12	16	0	10	20	4	40	176
Unknown	9	1	33	16	31	2	26	13	8	40	179
TOTAL	12	2	115	28	47	2	37	33	12	81	369

* Breeds that are also recorded in countries outside Africa are excluded from the analysis.

Figure 3.15: The risk status of livestock breeds recorded in North and West Africa* as of December 2005: absolute (table) and relative (chart) figures. Source: FAO (2007b).



RISK STATUS	Chicken	Duck	Goose	Guinea fowl	Muscovy duck	Ostrich	Pigeon	Quail	Turkey	TOTAL
Extinct	0	0	0	2	0	0	0	0	0	2
Critical	0	0	3	0	0	3	0	0	1	7
Endangered	1	0	0	4	1	0	3	0	0	9
Not at risk	40	7	1	8	1	1	2	0	7	67
Unknown	43	6	2	18	2	0	1	1	3	76
TOTAL	84	13	6	22	4	4	6	1	11	161

* Breeds that are also recorded in countries outside Africa are excluded from the analysis.

Figure 3.16: Risk status of avian domestic breeds recorded in North and West Africa* as of December 2005: absolute (table) and relative (chart) figures. Source: FAO (2007b).

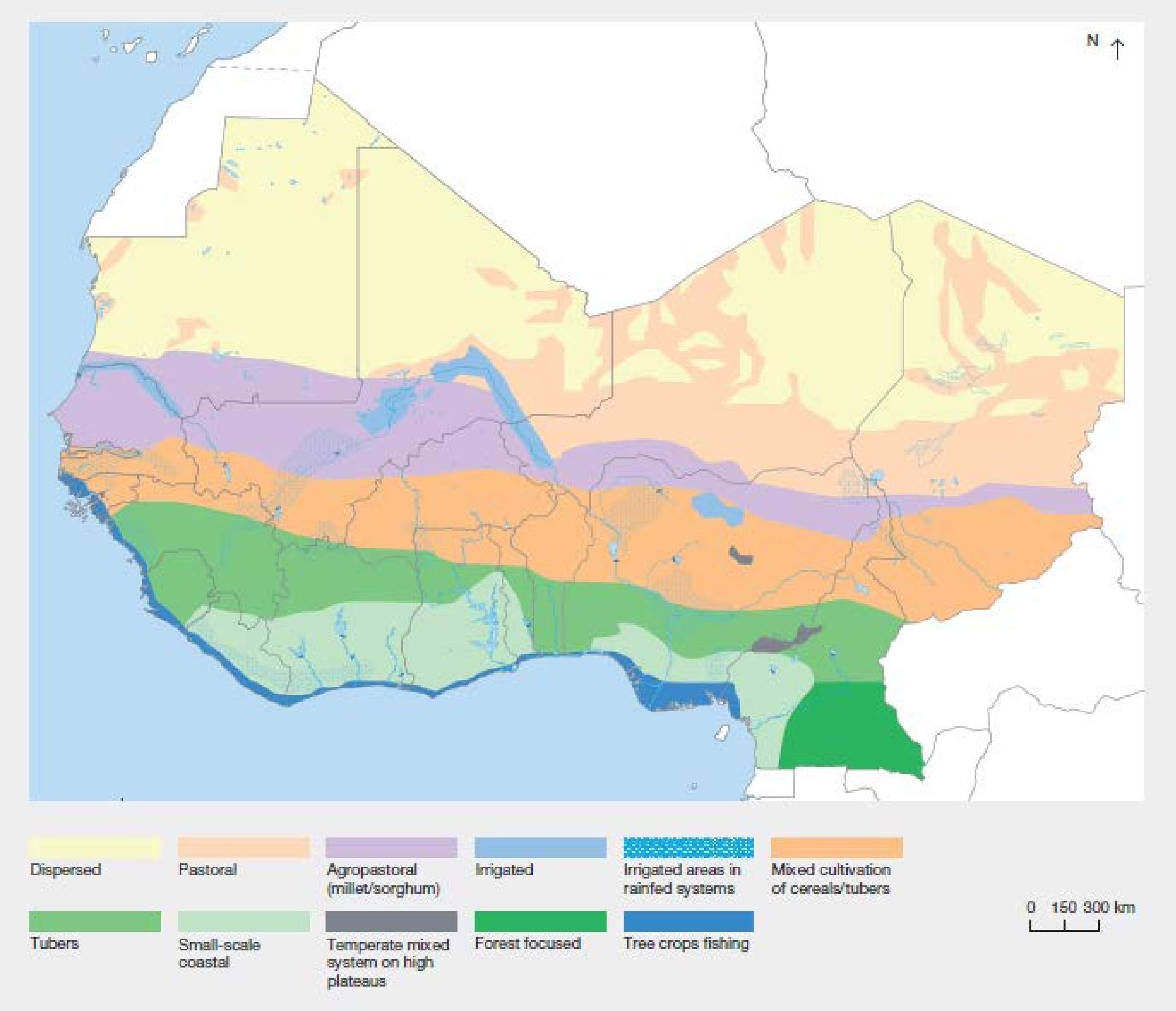


Figure 3.17: Major production systems in West Africa. Source: Blein *et al.* (2008).

Future dynamics: In the absence of high-level farmer and institutional response, most of these income crops are likely to decline due to drought, given that irrigation is financially out of reach for the vast majority of producers (e.g., Schroth *et al.*, 2016).

3.4.4.2. Aquatic (Freshwater, Marine and Coastal)

3.4.4.2.1. Wetlands

Status and trends: Outstanding wetlands that harbour very high numbers of migratory and wintering waterfowl are found in West Africa. They include the Inner Niger Delta in Mali, Lake Chad and Hadejia-Nguru wetlands in Nigeria (CEPF, 2015). In Niger alone, wetlands are estimated to hold 1.2 million waterbirds (Brouwer *et al.*, 2001), whereas the Senegal River Delta is home to over 3 million wintering shorebirds, at least 108 bird species of nesting piscivorous birds and is one of the 3 transfrontier Biosphere Reserves of Africa (Bouamrane *et al.*, 2016). Of the 46 Critical sites identified in West Africa, 10 sites holds highest number of migratory waterfowl (e.g., *Arcocephalus paludicola*) (CEPF, 2015).

Threats to West Africa's mangroves and wetlands, and their associated biodiversity and ecosystem services are linked to a growing population, industrial and agricultural development and a changing climate (Hamerlynck *et al.*, 2003; Sy *et al.*, 2015). Coleman *et al.* (2008) showed that between 1987 and 2002, in an area of 1,110 km^2 of the lower Niger delta, approximately 88 km^2 of wetlands had been converted to open water or converted to agricultural activities. Current levels of water extraction have also impacted wetlands, as exemplified by Lake Chad, which has shrunk from a surface area of 25,000 km^2 in the early 1960s to around 1,350 km^2 in 2001 (Smith *et al.*, 2009). According to Thieme *et al.* (2005) 12 of 17 freshwater ecoregions are either listed as Critical or Endangered and the region contains over a third of all the ecoregions in Africa listed as Critical.

Future dynamics: In West Africa, mangroves are found discontinuously from Senegal to the Niger Delta, however, these mangroves are in moderate decline, with an estimated average decline of 25% between 1980 and 2006, then recovering in a few countries in the last decade. The decline is due to cutting of the trees for fuelwood and poles for housing construction; urbanisation and industrialisation; the use of poison and dynamite for fishing, canalisation, discharge of sewage and other pollutants, siltation, sand mining, erosion, construction of embankments; and in some areas, from the damming of the Volta River. Apart from declining mangrove ecosystems in West Africa, a study by Belle *et al.* (2016) revealed that in term of proportions, by 2040–2069, 80% of the assessed will be vulnerable to climate change. Of the 202 species identified as climate change vulnerable by 2040–2069, 62 are globally threatened.

3.4.4.2.2. Inland surface waters and water bodies/freshwater

Status and trends: The inland waters of West Africa supports a high diversity of aquatic species with high levels of endemism (Smith *et al.*, 2009). High endemism of the species is due to the various different habitat types from the dry Sahel in the north, moving south through grassland and into tropical moist forests near the coast. Covering the northern part of the region in Niger, Mali, Mauritania and Chad is the Sahel, a dry region, characterized by scattered oases, semi-permanent pools and temporary rivers, which receives on average just 30-50 millimetres of rain/year (Thieme *et al.*, 2005). These freshwater bodies are of economic importance to both locals and nations in the region. The value of fisheries production for the major river systems in western Africa is estimated to be over $200 million/year (FAO, 2009b).

Inland waters of the Upper Guinean Forests support approximately 1,281 species of fishes, of which 38% are considered endemic (Paugy *et al.*, 2003), 155 species are globally threatened (Smith *et al.*, 2009). Threats to these species are mainly anthropogenic and as human populations increase throughout the region, the pressures on these inland waters and its biodiversity is going to rise as well. The immediate priorities for conservation actions to be taken are fully comprehensive Environmental Impact Assessments, designation of areas with high levels of biodiversity as Protected Areas and filling the information gap (large number of species fall into the data deficient category of the Red List).

3.4.4.2.3. Shelf-ecosystem

Status and trends: The narrow coast (generally less than 100 km on average) is home to approximately 148 species of seabirds and marine seabirds (CEPF, 2015). Biodiversity is related to the type of coastal habitat rocky beaches occur on less than 3% of the coastline, sandy beaches (16%), headlands and coves (14%), areas associated with estuaries, river mouths and lagoons (19%), and mangroves (48%) (Diop *et al.*, 2014). Sea-grass beds are not well developed in the region and there are no true reefs due to intrusion of cool waters of the Benguela and Canary currents and high turbidity of the waters. All countries in the region are signatories to the Ramsar Convention, with 37 designated sites within the coastal marine zone. The beaches are especially important for five of the seven species of marine turtles that are globally threatened.

The coastal ecosystems support highly diverse faunal and floral communities, including fish and invertebrate fauna, many of which are important commercial species. In West Africa, mangroves are found discontinuously from Senegal to the Niger Delta. Six species of trees are found (Table 3.6). Mangroves, estimated at 13,898 km^2 (Tang *et al.*, 2014), provide many important ecological functions. They support the subregion's fisheries which contribute $400 million annually to the total economy and can sequester up to 1,000 tons of carbon, three times more than tropical rainforests (Rotich *et al.*, 2016). The largest areas are in Guinea-Bissau and Nigeria, representing 2.5% and 4.7% of the global total areas of mangroves globally, respectively (Giri *et al.* 2011). Trends from 1975 to 2013 however show a decline of 4.8% in mangrove area (984 km^2) due to overexploitation and changing land-use. Increasing pollution from agricultural, industrial, domestic activities, petroleum exploitation and exploration, have negative implications on the species composition and ecological balance in these ecosystems (Church *et al.*, 2010).

Coastal ecosystems are internationally important for migratory waterfowl (Senegal Delta, coastal lagoons of Ghana), and for manatee (Niger Delta) and for shellfish and juveniles fish. The Niger Delta provides spawning/nursery areas for the fisheries in the Gulf of Guinea. A high diversity is found in the pelagic fish community, with 48 species in 38 families (Ajao, 1993). Pelagic families and species associated with them include Clupeidae (*Ethmalosa fimbriata*, Least Concern), *Pellonula leonensis* (Least Concern), *Ilisha africana* (Least Concern), *Sardinella maderensis* (Vulnerable*), Belonnidae, Ablennes hians* (Least Concern), *Strongulura senegalensis*), Megalopidae (*Tarpon atlanticus*), Hemiramphidae (*Hyporhamphus Picarti*, Least Concern), Elopidae (*Elops lacerta*, Least Concern), *E. senegalensis*), and Albulidae (*Albula vulpes,* Near Threatened) (Isebor *et al.*, 1993; Shumway, 1999). West African manatee (*Trichechus senegalensis*, Vulnerable) (Hughes *et al.*, 1992), the soft-skinned turtle (*Trionyx triunguis,* Vulnerable), and in the Niger Delta, isolated populations of pygmy hippopotamus (*Hexaprotodon liberiensis heslopi*, Vulnerable) are the most remarkable fauna. Besides, five species of marine turtle, leatherback (*Dermochelys coricea*, Endangered), loggerhead (*Caretta caretta*, Endangered), olive ridley (*Lepidochelys olivacea*, Vulnerable), hawksbill (*Eretomychelys imbricata*, Critically Endangered), and green turtles (*Chelonia mydas*, Endangered).

The Upper-Guinea Coast, from Saloum Delta in Senegal to Sierra Leone, contain the most-inhabited (human density up to 40–80 houses/km^2) and best-developed mangroves in West Africa (8,507 km^2) (Ruë, 2002). Oysters found in this region include species s such as C*rassostera gazar*, and cockle species like: *Anadara senilis*, *Galatea paradoxa*, *Murex hoplites*, *Murex cornutus*, *Orbicularia orbiculat*, *Pugilina morio*, *Cymbium* spp., *Cultellus tenuis* (Cormier-Salem, 1999). Same as Mangroves found in other parts of Africa are threatened by drought, rural exodus and the coastal erosion, being translated by the salinization and the acidification of muddy soils. More than 25% of the mangrove trees have been lost (Conchedda *et al.*, 2011; Temudo, 2012; Carney *et al.*, 2014; Zwarts, 2014; Cormier-Salem *et al.*, 2016; Temudo *et al*., 2017). In 2015, mangrove forests occupied 349,555 hectares of the territory of Guinea-Bissau which corresponds to an annual change rate of 1.54% (Temudo *et al*., 2017).

<u>Future dynamics:</u> Development partners have supported mangrove conservation efforts at different scales, notably the West Africa Marine and Coastal Conservation Platform for Mauritania, Senegal, the Gambia, Guinea-Bissau, Guinea, Sierra Leone and Cape Verde. It is the most important example of coordinated mangrove conservation partnership and led to the adoption by the six countries of a Mangrove Charter and subsequent national action plans.

3.4.4.2.4. Open Ocean

Status and trends: Off the coast is the Guinea Current Large Marine Ecosystem (GCLME) with distinctive bathymetry, hydrography, chemistry and tropho-dynamics that make it one of the top five most productive large marine ecosystems in the world in terms of biomass yields. Periodical upwelling of deeper nutrient-rich cold water to the surface (mainly July to September each year) contributes to the high average primary productivity of 392 grams of Carbon/m^2/year that causes a high biological activity and increased fish spawning. Marine biodiversity has been estimated at 1,811 species (Polidoro *et al.*, 2017). A value of €872 million has been estimated for selected regulation services such as water treatment, carbon sequestration and coastal protection (Interwies, 2010; Interwies *et al.*, 2013). The fishery resources, estimated at about 239 fish species (Ukwe *et al.*, 2006), is made up of locally resident stock as well as transboundary straddling and migratory stocks. Exploited species include small pelagic fishes, large migratory pelagic fishes such as tuna and billfishes, crustaceans, molluscs and demersal fish. Total reported landings (composed of mixed species due to poor categorisation of species at landings) have generally increased, from approximately 567,000 tons in the 1950s to a peak of 4.8 million tons in 2000, after which it declined to less than 4.4 million tons in 2010 and 2014 (Belhabib *et al.*, 2015; FAO, 2016). Small pelagics constitute almost 50% of landings and demersal resources in most areas are considered to be either fully fished or overfished (FAO, 2016).

Fisheries and overharvesting are the biggest threat to marine resources, affecting 87% (109 of 125 species) of threatened species, followed by habitat loss and coastal development affecting 55% of threatened species (69 of 125) (Polidoro *et al.*, 2017). Combination of habitat loss and overharvesting, in addition to natural environmental variations, is leading to significant changes in species composition over time, with the size spectrum of fish becoming smaller. With climate variations, annual landed value is estimated to decrease by 21% with an annual loss of $311 million for the entire economy of the region by 2050s (Badjeck *et al.*, 2010). The region is operating below its optimum level of ocean health and falls in the highest risk group, scoring a low 58 out of 100 on its ocean health index, compared to other large marine ecosystems (Kershaw *et al.*, 2016). The marine trophic index has also declined since the mid-1970s although there has been 18.57% increase in the coverage of marine protected areas between 1983 and 2014, from 829 km^2 to 16,216 km^2, respectively (Robin *et al.*, 2015).

3.4.4.2.5. Deep sea

In general, information about the deep sea megafauna is limited, although the echinoid *Phormosoma placenta* is known as a common and abundant species in the subregion (Jones *et al.*, 2013). More than 650 deep-water and near-shore species of marine bony fish have been recorded in West Africa (CEPF, 2015). Of the 87 species of sharks and rays assessed, 54% are found to be threatened (CEPF, 2015).

3.4.5. Southern Africa

3.4.5.1. Terrestrial

3.4.5.1.1. Tropical and subtropical dry and humid forest

Status: The tropical dry forests of Southern Africa are located in Zambia, encompassing approximately 38,073 km^2 of dry evergreen forest (WWF, 2017b). These forests represent a transition from Guineo-Congolian rainforest to Zambezian woodlands and are species-rich, but contain few endemics such as *Crypotsepalum exfoliatum pseudotaxus*, known locally as "mavunda" (WWF, 2017b). These forests in Zambia are a home to 17 species of amphibians, 175 species of birds, 89 species of mammals, 9 species of reptiles and 30 species of plants (IUCN, 2017). In South Africa, forest covers only about 17,600 km^2 (Table 3.10), though there are patches of forest located within the savannah biome (Table 3.11).

Table 3.10: The average fraction of the ‘natural populations of plant and vertebrate groups estimated to remain in the major biomes of South Africa. Source: van Jaarsveld *et al.* (2005).

	Area (km^2)	Plants	Mammals	Birds	Reptiles	Amphibia	All taxa
Forest	176,893	0.75	0.75	0.92	0.86	0.85	0.78
Savana	2,329,550	0.86	0.73	0.96	0.89	0.96	0.87
Grassland	408,874	0.72	0.55	0.90	0.76	0.81	0.74
Shrubland	750,217	0.86	0.72	1.06	0.93	1.27	0.89
Fynbos	78,533	0.75	0.78	0.91	0.77	0.79	0.76
Wetland	95,166	0.91	0.83	0.94	0.92	0.95	0.91
All biomes	3,839,233	0.82	0.71	0.96	0.88	0.95	0.84

Table 3.11: Biodiversity status in the three major Gariep biomes. Source: van Jaarsveld *et al.* (2005).

Biome	Area (km^2)	Species richness[1]	Endemic spp.[2]	Endangered spp.[3]	Protected area[4] (%)	Transformed area[5] (%)
Grasslands	215,508	1,377	144	112	2.7	28.8
Savannah	190,646	1,424	106	102	10.6	6.7
Nama Karoo	237,147	979	99	73	1.3	1.5

1: Species data for birds, butterflies, mammals, reptiles and scarabs from SA-ISIS (http://spatial.csir.co.za/website/).
2: Endemic to South Africa.
3: Endangered if listed in the Red Data Books for birds and mammals. Other taxa assessed by expert opinion.
4: Based on data from Department of Water Affairs and Forestry (DWAF), Pretoria, South Africa.
5: Based on National Land-Cover Database (Thompson 1996).

Trends: About 40% of Zambian primary forest has been lost particularly in the northern region (Zambia, 2015). This trend is evident in the rapid depletion of Zambia’s natural forests with the deforestation rate currently estimated between 250,000–300,000 hectares/year. According to Chidumayo (2013), Zambia has lost a significant portion of its forest cover since 1990 to 2012 with impacts on wood biomass (Figure 3.18) an important contribution of nature to people. Indeed forest degradation was estimated to cause aboveground wood biomass loss of 0.3 tons/hectare/year on the least impacted site to 4.0 tons/hectare/year on the most impacted site. The biodiversity of the Southern African dry forests in Zambia is slightly declining, with 2.85% of bird species, 5.61% of mammal species and 6.66% of plant species threatened to extinction (IUCN, 2017).

A decline in forest area has also been seen in South Africa which consist of Afrotemperate forests that are mainly found in the southern Cape region and other areas where there are ravines protected from fire. For example, since 1944, when there were 7,143 hectares of indigenous forest in the Karkloof-Balgowan region, there has been a 5.7% decline in forest area to 6,739 hectares in 1996 (Lawes *et al.*, 2004).

Future dynamics: The Zambezian dryland forests of Angola and Zambia appear not be threatened in the near to medium term due to the small human population, poor agricultural potential and lack of water (WWF, 2017b). However, in South Africa, there has been a decrease in the area of natural forest between 1990 and 2015. According to Biggs *et al.* (2008), the observed erosion of forest in South Africa is due to land conversion for cultivation and is predicted to suffer the most dramatic loss in future.

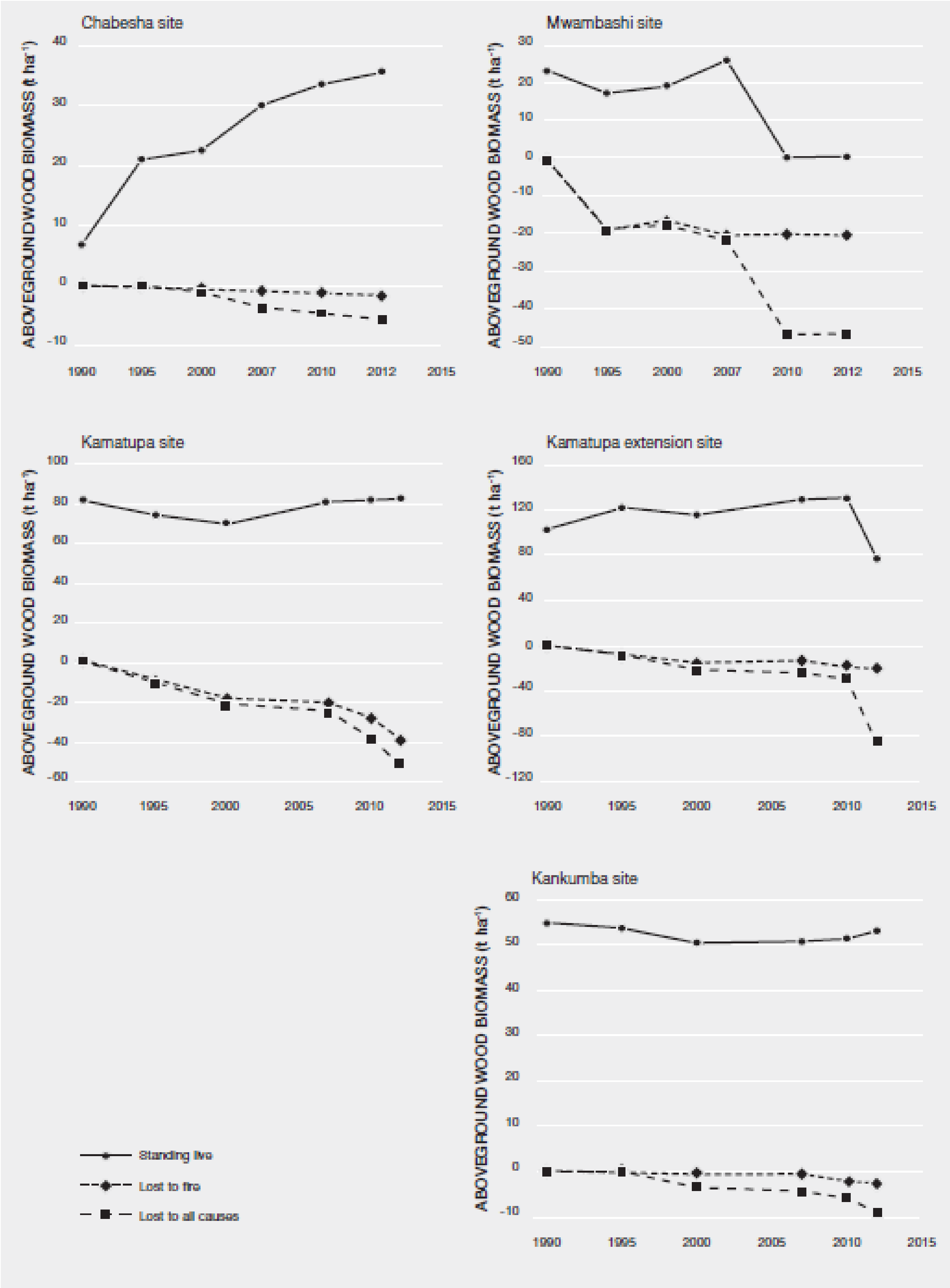


Figure 3.18: Zambia: Trends in aboveground wood biomass in Zambia where the largest portion of forest exist in Southern Africa. Source: Chidumayo. (2013).

3.4.5.1.2. High mountain habitats and Grassland

Status: The two major mountain formations in Southern Africa are the Southern African Great Escarpment, and the Cape Fold Mountains. These mountains provide a range of ecosystem services including water catchments, food production (both grazing and crops), forestry plantations or mining and tourism (Blignaut *et al.*, 2010).

The Southern African Great Escarpment extends in a 5,000 km horse-shoe formation from the border between Mozambique and Zimbabwe in the north-east, through South Africa and Lesotho to Namibia and Angola in the northwest. The Great Escarpment provides most of the freshwater in Southern Africa and is home to an estimated 8,574 plant species, of which 17% are endemic (Clark *et al.*, 2011). Vegetation types vary with altitude and rainfall, ranging from tropical evergreen and semi-deciduous rainforest in northern Angola, through to Afromontane forest-grassland mosaics and miombo woodland, through to Highveld shrublands, Nama-Karoo semi-desert, and fynbos (Clark *et al.*, 2011). There are also many endemic fauna in the montane areas of Southern Africa and include mammals such as the oribi, reptiles such as the cream-spotted mountain snake (*Montaspis gilvomaculata*), cottrell's mountain lizard (*Tropidosaura cottrelli*, Near Threatened) and essex's mountain lizard (*T. essexi*, Least Concern). It also includes amphibians such as the Maluti river frog (*Amieta umbraculata*) and the Phofung river frog (*A. vertebralis*) (Perera *et al.*, 2011). Lesotho's Sehlabathebe national park also harbours the Maloti minnow (*Pseudobarbus quathlambae*, Endangered), a critically endangered fish species only found in this park. Range-restricted birds include the Drakensburg Rock-jumper, Drakensburg Siskin as well as a breeding stronghold for Cape and Bearded vulture (Perera *et al.*, 2011).

Data availability and conservation capacity varies along the escarpment, the most data deficient area being Angola and the best studied being the east (South Africa, Lesotho and Swaziland). The Great Escarpment Biodiversity Programme is a multi-disciplinary collaboration that aims to collect biogeographical data of relevance to conservation policy and predicting future responses of montane ecosystems. There are several transfrontier conservation initiatives, including the Richtersveld transfrontier national park between Namibia and South Africa, the Maloti–Drakensberg Transfrontier Park between South Africa and Lesotho, and the Chimanimani transfrontier conservation area between Zimbabwe and Mozambique.

The highest mountain ranges of the Great Escarpment are the Drakensberg (altitude 2,000–3,000 metres). The Drakensberg are characterized by high altitude grasslands with over 2,500 species of higher plants. The Maloti-Drakensberg Park which is a transboundary site is composed of the uKhahlamba Drakensberg national park in South Africa and the Sehlabathebe national park in Lesotho. Maloti national park in South Africa was designated specifically to protect water catchments (Egoh *et al.*, 2012).

Vegetation of the Cape Fold belt is primarily fynbos, a species-rich, fire-prone shrubland that is unique to Southern Africa. Afrotemperate forests co-exist alongside fynbos, in wetter areas that are protected from fire. The Cape Fold Belt is an important part of the Cape Floristic Region, one of 25 global biodiversity hotspots (Mittermeier *et al.*, 1998). It is the smallest and richest internationally recognised floral kingdom containing more than 9,000 plant species, of which 68% are endemic (Myers *et al.*, 2000; Rejmánek, 2001; Manning *et al.*, 2012). It is a global conservation priority because of species richness, endemism, and rates of transformation; about 30.3% of its primary vegetation has already been lost.

Trends: Land outside of protected areas is threatened existing and emerging invasive alien species (especially Australian Acacias), including pollution /mining impact, and habitat loss, the compounding effects of climate change as well as by growing numbers of high density rural settlements, particularly in the KwaZulu-Natal Drakensberg foothills (Blignaut *et al.*, 2010, Clark *et al.*, 2011, Egoh *et al.*, 2011; Turpie, 2016).

Future dynamics: Projected increases in temperatures, decreases in precipitation and longer dry seasons are likely to become important drivers of change in Southern African mountain systems. Direct impacts include physiological stress, mortality and range shifts in species, and altered composition and function at ecosystem levels. Resulting changes in fire regimes are likely to have important indirect impacts on the region's biodiversity. Climate change also presents an important threat to water and food security in Southern Africa. An estimated 97% of Cape Town's water originates from surface water from mountain catchment areas (Lonsdale *et al.,* 2009). At the time of writing, Cape Town's dammed water reserves were at 24% despite severe water restrictions (City of Cape Town, 2017). Ingoing immigration and population growth in the region is likely to exacerbate water shortages in the future.

3.4.5.1.3. Savannah and grassland

Status: The savannas and grasslands represent the largest area in Southern Africa occupying 54% of its territory (Cowling *et al.*, 1997) covering about 139,000 km^2. It contains within it vegetation types such as Miombo, Mopane, Zambezian and Kalahari Acacia-Baikiaea Woodlands as well as the Kalahari Xeric Savanna (Cowling *et al.*, 1997). Many of these savanna vegetation types are utilized for grazing by livestock animals or wildlife. The subregion boasts an average of 57 mammalian species and 136 breeding bird species per 10,000 km^2 (UNEP *et al*., 2002). Southern Africa's rich biodiversity plays an important role in ensuring long-term food security and provision of basic materials to people especially rural people who make up approximately 60% of the total population in most countries in the region (World Bank, 2016). Also, about 10% of Southern African plants (roughly 3,000 species) are used medicinally, and about 350 species are widely utilized (van Wyk *et al.*, 1997). Much of the savanna is under protection with the existence of large game Parks such as Kruger National Park in South Africa and Hwange in Zimbabwe and many private game reserves, safaris and conservancies (SANBI, 2017) complemented by the existence of Transfrontier Conservation Areas such as Great Limpopo. This also provides important economic benefits from tourism and big game hunting.

Trends: The savanna terrestrial unit of analysis itself is under pressures such as expansion of agriculture and plantation forestry, poaching, spread of invasive alien species, human settlements, mining activities, and other commercial or subsistence activities, both inside and outside of protected areas (UNEP *et al*., 2002). Poaching continues to be a problem and 1004 rhinos were killed by poachers in South Africa in 2013 alone (RSA, 2014). Threatened vegetation types within Savannah include Tzaneen Sour Bushveld and Lebombo Summit Sourveld (Mucina *et al.*, 2006). Individual species are also threatened and declining in numbers and diversity (UNEP *et al.*, 2002). Threatened vegetation types within the Grassland Biome include the Northern Escarpment and the Woodbush Granite Grassland (Mucina *et al.*, 2006). High altitude grasslands are threatened by agriculture, mining and commercial forestry, as well as inappropriate fire management, overstocking and soil erosion (Blignaut *et al.*, 2010; Clark *et al.*, 2011, Egoh *et al.*, 2011), and a growing numbers of high density rural settlements, particularly in the KwaZulu-Natal Drakensberg foothills.

Future dynamics: At current rates of urbanisation coupled with climate change, the savanna terrestrial unit and the individual species within it are likely to continue declining if no concerted efforts are made at policy level to reverse this trend. Currently, there is an emerging trend for increasing woody vegetation with the possibility of biome switches between savanna and forest vegetation types driven by CO_2 enrichment (Higgins *et al.*, 2012).

3.4.5.1.4. Dryland and desert

Status: In Southern Africa, dryland and desert are diverse and are represented by various ecosystems such as the Succulent Karoo, Namib Desert, Nama Karoo and the Kalahari Desert and xeric savanna (WWF, 2017a). The Succulent Karoo stretches from the western coast of Namibia to South Africa (Jürgens *et al.*, 1999), covering an area of approximately 102,000 km^2 (WWF, 2017a). In terms of species diversity, the Succulent Karoo boasts about 5000 higher plant species of which 40% are endemic and has the highest succulent diversity in the world with about 1,000 species (435 species of miniature succulents and 630 species of geophytes) (WWF, 2017a). Also, about 67 genera and 1,940 species of both flora and fauna are endemic to this region which is made up of 4 centres of endemism (Hilton-Taylor, 1994). For these reasons, the Succulent Karoo qualifies as a global biodiversity hotspot (CEPF, 2016). Less than 3% of the succulent Karoo is protected in statutory reserves (WWF, 2017a) but two new developments are positive signs for the future of the Succulent Karoo. These include the creation of the Namaqua national park which is set to expand westwards to encompass Sandveld habitats on the coastal plain. Also, public awareness of the value of the region is growing through the Succulent Karoo Ecosystem Programme which among other actions is leading to increased efforts of landowners in the region to adopt biodiversity-friendly land-use patterns (Loon, personal communication).

The Namib Desert is the world's oldest and has been arid for 55 million years (Barnard *et al.*, 1998). It is home to many endemic species adapted to the hyper-arid conditions, and coastal fog. The desert hosts 70 reptile species, of which 20 are endemic, and the popular gymnosperm plant, *Welwitschia mirabilis,* the Namibian wolf snake (*Lychophidion namibianum*) and amphibian Damaraland pygmy toad (*Poyntonophrynus damaranus*) are also endemic here. Most of the Namib Desert is protected in conservation areas (Maggs *et al.*, 1998). The Nama Karoo is confined to the Northern, Western and Eastern Cape Provinces of South Africa (WWF, 2017a) and has low species diversity and endemism (WWF, 2017a). Vegetation here is dominated by members of the Asteraceae, Poaceae, Aizoaceae, Crassulaceae and Fabaceae (Palmer *et al.*, 1997; Mucina *et al.*, 2006). Very little of the Nama Karoo is protected (Barnard *et al.*, 1998).

Transnational, is the Kalahari xeric savanna which stretches from north-western South Africa through southern Botswana to south-eastern Namibia (WWF, 2017a). The Kalahari Desert is considered to have the lowest species diversity and animal endemism in southern Africa (van Rooyen, 1999). The Kalahari Desert is relatively well conserved with protected areas such as Kgalagadi Transfrontier Park which cover more than 34,000 km^2.

Trends and future dynamics: All ecosystems in this terrestrial unit are facing decline due to anthropogenic disturbances such as overgrazing, mining, illegal harvesting of succulents, disruptive off-roading activities by tourists, unregulated water extraction affecting water table, veterinary fences hindering ungulate migration, human-wildlife conflicts and alien invasive species (Albertson, 1998; Lovegrove, 1993; WWF, 2017a). Charismatic species with declining populations include halfmen (*Pachypodium namaquanum*, Lower Risk/near threatened), quiver trees (*Aloe dichotoma*) and *Aloe ramossisima* (WWF, 2017a). The African wild dog is most severely threatened especially in the Nama Karoo (Hilton-Taylor, 2000). The drylands and desert in Southern Arica will continue to decline unless activities such as mining are halted and more protected areas are established.

3.4.5.1.5. Urban/Semi-urban

Status and trends: Urbanisation is increasing rapidly in most parts of Southern African particularly South Africa and Zambia, where more than 50% of the population already live in urban areas (Mwendera, 2010). In South Africa, urbanisation is most rapid in Johannesburg or the wider Gauteng province area. By 2014, the Johannesburg area is in the 5–10 million category (although some debates regarding numbers have been engaged in, as well as consideration of the greater municipality area). By 2014, Luanda also fell within the 5–10 million size category. By 2030, the World Urbanisation Prospects 2014 analysis predicts the Gauteng area as a 10 million or more megacity, although no hotspots of 100% probable expansion to urban areas are found in the Seto *et al.* (2012) analysis.

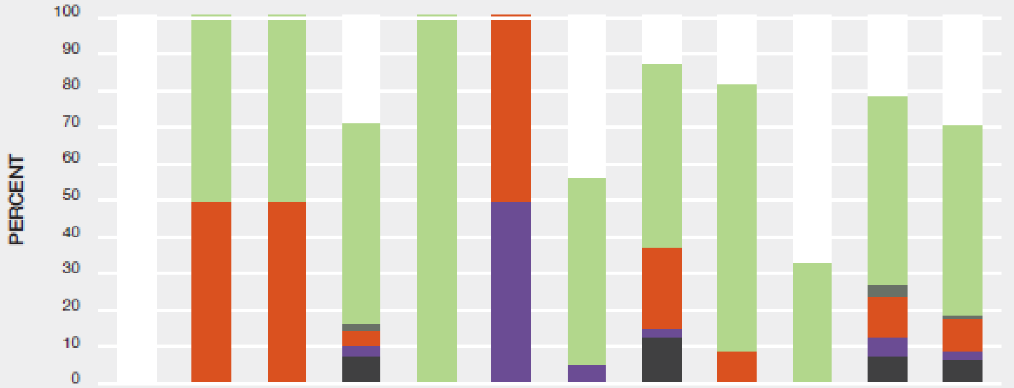
Future dynamics: About 59% of the population of Southern Africa lives in urban areas, and is predicted to increase to 78% by 2050 (UN-habitat, 2010).

3.4.5.1.6. Cultivated lands

Status and trends: The agrobiodiversity in Southern Africa, as in other parts of Africa and globally, is of great importance at both small scale and large commercial farmers through its provision of ecosystem services (FAO, 2007a). The cultivated lands in Southern Africa represents 40–60% of the land cover, with 53 known green vegetables/crops, of which 27 are underutilized and 26 are major commercial crops (Mabhaudhi *et al.*, 2016). An example of major commercial crops would be maize–a major source of livestock feed, and export crops in some countries (van Wyk *et al.*, 2000). Southern Africa is also endowed with a great variety of indigenous/traditional fruits commonly known as crop wild relatives, and non-domesticated animals. About 1,593 taxa (species, subspecies and varieties) of crop wild relative species are known in Southern Africa, 258 of these have been selected as focal species based on their conservation status, level of endemism, current economic value, their use as food and their breeding potential (Mogale *et al.*, 2017). Among the 404 known mammalian and avian breeds in Southern Africa, 44 are categorised as at risk (FAO, 2007a; Figure 3.18 & 3.20). However, this is probably an underestimate of the actual situation, primarily because of a lack of information (FAO, 2007a).

Southern Africa is a home to several distinct farming regions and farming activities range from intensive crop production, to cattle ranching in the bushveld and sheep farming in the more arid regions (Auricht *et al.*, 2014). These farming systems have become inadequate to cope with population growth explosions and lack investment in African farming systems that are experienced in the region (FAO, 2007a).

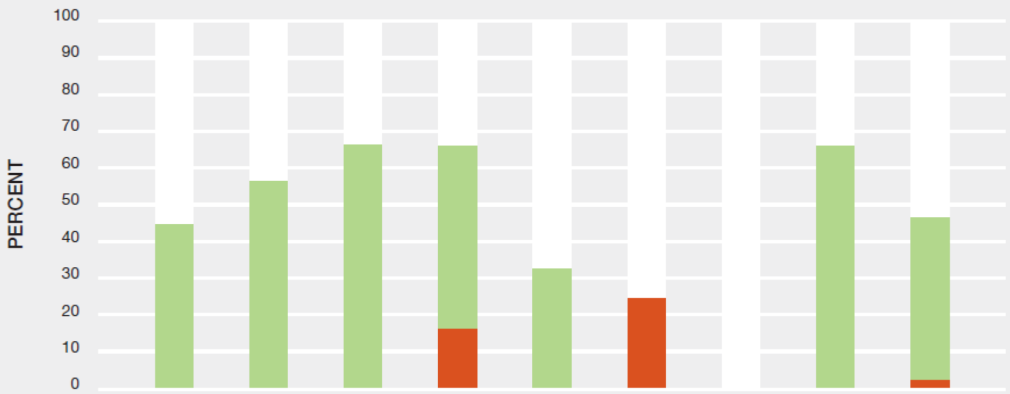
Future dynamics: Interesting changes in food consumption and production due to population growth have been evident since the 1970s in Southern Africa in particular South Africa (WWF, 2017e). The average production of maize for instance in South Africa has remained constant over time since 1970s (WWF, 2017e). This is a concern, as consumption has increased with the growing population and maize production may soon not meet local demand, affecting both local and regional supply. Apart from population growth, water scarcity and climate change is compelling farmers to the move toward genetically modified crops in South Africa. This shift in itself will not only impact biodiversity in cultivated lands but it presents Southern Africa with a possibility of being isolated from lucrative export markets (WWF, 2017e).



RISK STATUS	Alpaca	Ass	Buffalo	Cattle	Deer	Dromedary	Goat	Horse	Pig	Rabbit	Sheep	TOTAL
Extinct	0	0	0	9	0	0	0	5	0	0	5	19
Critical	0	0	0	3	0	1	2	0	0	0	3	10
Endangered	0	1	1	6	0	1	0	9	3	0	7	28
Endangered maintained	0	0	0	2	0	0	0	0	0	0	2	4
Not at risk	0	1	1	71	1	0	22	20	18	4	34	172
Unknown	1	0	0	37	0	0	19	5	13	8	14	97
TOTAL	1	2	2	128	1	2	43	34	34	12	65	330

* Breeds that are also recorded in countries outside Africa are excluded from the analysis.

Figure 3.19: Risk status of livestock breeds recorded in Southern Africa* as of December 2005: absolute (table) and relative (chart) figures. Source: FAO (2007a).



RISK STATUS	Chicken	Duck	Goose	Guinea fowl	Muscovy duck	Ostrich	Pigeon	Turkey	TOTAL
Endangered	0	0	0	1	0	1	0	0	2
Not at risk	21	4	2	3	1	0	0	2	33
Unknown	26	3	1	2	2	3	1	1	39
TOTAL	47	7	3	6	3	4	1	3	74

* Breeds that are also recorded in countries outside Africa are excluded from the analysis.

Figure 3.20: Risk status of avian domestic breeds recorded in the Southern Africa* as of December 2005: absolute (table) and relative (chart) figures. Source: FAO (2007a).

3.4.5.2. Aquatic (Freshwater, Coastal and Marine)

3.4.5.2.1. Freshwater

Status: Southern Africa's wetlands are among the most diverse, both physically and biologically of any in the world (Taylor *et al.*, 1995; Darwall *et al.*, 2009). A systematic assessment of river biodiversity revealed that 84% of river ecosystems are threatened, including 54% critically endangered (Nel *et al.*, 2007). Of the 1,279 freshwater species assessed at the regional scale, just over 7% are regionally threatened (Darwall *et al.*, 2009).

Trends: Freshwater ecosystems and species are threatened by habitat loss and degradation, including groundwater extraction and dam construction, pollution (e.g., from mining waster, and over-harvesting, and alien invasive species (Darwall *et al.*, 2009; Darwall *et al.*, 2011). Invasive alien species include deliberately introduced exotic fish (e.g., *Micropterus dolomieu*, Least Concern, *Oncorhynchus mykiss* and *Salmo trutta*, Least Concern, and species of the cichlid genus *Oreochromis*) and invasive plants such as the water hyacinth, and black wattle which invades riparian corridors. Increasing development pressure is expected to lead to deterioration in the status of southern Africa's freshwater biodiversity. Water transfer schemes are also a threat to lake ecosystems, as they allow mixing of previously separated populations of fish, with the potential for competition, predation and hybridization (Darwall *et al.*, 2011).

Future dynamics: Climate change and climate variability, especially increased frequency of drought are likely to further impact freshwater systems that are already stressed by multiple factors.

3.4.5.2.2. Shelf-ecosystem

Status: The coastal areas extend along the 10,000 km of coastline from Angola on the Atlantic Ocean side to Tanzania on the Indian Ocean side. Near-shore ecosystems of Southern Africa include cold temperate (Atlantic), warm temperate, and sub-tropical (Indian Ocean), which experience different stressors and have varied responses to climate change. Fisheries on the cold temperate west coast of southern Africa are fed by the nutrient-rich waters of the Benguela upwelling system. Anchovy and sardine are the dominant species in pelagic fisheries. Excessive fishing pressure led to the collapse of Namibian and South African sardine, beginning in the 1960s. The demersal fish community has also changed, with a decline in slower-growing long-lived species. West coast rock lobster populations have also declined dramatically due to a combination of overfishing and low oxygen water, and the species is now severely overfished (DAFF, 2014). The demise of prey populations has impacted on livelihoods, and also on predators such as sea otters, penguins, gannets and cormorants. Nevertheless, the west coast Benguela marine ecosystem is still productive, and there is no evidence that any species have been lost. Tourism is also an important source of gross domestic product and livelihoods, as are oil, natural gas and diamonds.

There is a rich coastal and marine biodiversity associated with the fringing and patch coral reefs and mangrove forests in Tanzania and Mozambique (UNEP, 2005a). Large stands of mangroves are found at the mouths of the Zambezi, Save, Pungue, and Limpopo rivers along the coastline of Mozambique. The dominant trees are *Rhizophora racemosa* (Least Concern), *R. mangle* (Least Concern), *R. harrisonii* and, *Avicennia Africana*. In Angola, mangrove communities occur at the mouths of the Cuvo, Longa, Cuanza, Dande, and M'Bridge Rivers (Huntley *et al.*, 1994), though they are not as extensive as the vast mangrove swamps at the mouth of the Zaire River. In South Africa, the distribution of mangrove forests (temperate and subtropical) is patchy and the drivers of the mangrove's distribution are still poorly understood. A changing climate that results in increased temperature may favour the expansion southward of mangrove forest in South Africa's estuaries (Hoppe-Speer *et al.*, 2013; Kairo *et al.*, 2016). In the Eastern Cape, mangroves are located in one of the most southerly mangrove distributions in the world (Hoppe-Speer *et al.*, 2013). Along the east coast of South Africa, 6 species in Kosi Bay (*Avicennia marina* (Least Concern), *Bruguiera gymnorrhiza*, *Rhizophora mucronata* (Least Concern), *Ceriops tagal* (Least Concern), *Lumnitzera racemosa* (Least Concern) and *Xylocarpus granatum* (Least Concern) and 3 in Nahoon (*Avicennia marina*, Least Concern, *Bruguiera gymnorrhiza* and *Rhizophora mucronata*, Least Concern) are found.

Mangroves are traditionally used for charcoal, firewood, building material for housing, fences and fish traps, but also for medicine (notably in Mozambique). Mangroves have also been considered efficient systems for the removal of nutrients and other pollutants (Lewis *et al.*, 2013). In response to drought and non-tidal conditions (as a result of mouth closure in St Lucia Estuary, South Africa), Hoppe-Speer *et al.* (2013) showed that mangrove species have difficulties in surviving such harsh conditions. Mozambique, the Foundation for the Conservation of Biodiversity is promoting mangrove conservation. In South Africa, Kosi, St. Lucia, Mfolozi and Mhlathuze Estuaries account for about 75% of mangroves and except Mfozoli that are protected.

Coral communities occur in shallow waters of Mozambique, Tanzania, and on the Maputoland Reef in KwaZulu-Natal, South Africa (Obura *et al.*, 2004). All five species of marine turtles occurring in South African waters are listed on the IUCN Red List as either ‘vulnerable’ or ‘endangered’, as well as the blue whale (*Balaenopteramusculus intermediais*, Endangered). Four other marine mammals occurring in South African waters are considered to be ‘vulnerable’ namely, Indian Ocean bottlenosed dolphin (*Tursiops aduncus*), Indian Ocean humpback dolphin (*Sousa plumbea*, Endangered), sperm whale (*Physetter microcephalus*) and Bryde’s whale (*Balaenoptera brydei*) (Atkinson *et al.*, 2005).

3.4.5.2.3. Open Ocean

Status: Offshore areas are important habitat for many threatened seabirds, turtles and deep water fish, but most offshore habitats remain unprotected and poorly studied (Sink *et al.*, 2011). Offshore to the limit of the exclusive economic zone on the Atlantic side, the seas are influenced by the cold, northward-flowing Benguela current large marine ecosystem, with highly productive upwelling supporting industrial-scale fisheries. The east coast, under the influence of the East African Coast Current flows northward along the coast of Tanzania and southward towards Mozambique while the Agulhas Currents, is sub-tropical in South Africa (UNEP, 2005b). These waters are moderately productive with an average of 150–300 grams of carbon per square metre/year with considerable spatial variability in the productivity. Ecosystem goods and services have been estimated between $54.3 and $269 billion/year (Costanza *et al.*, 2014).

The marine resources of Southern Africa are rich and diverse, with commercial and recreational fisher catch at over 250 marine species (Mann, 2000). High catches have significantly decreased between 1965 and 1989, with stable total production capture of 1.4 million tons/year in the last decade, which mainly come from the exclusive economic zones of Angola, Namibia and South Africa (FAO, 2016). The Southeast Atlantic has shown a decreasing trend in catches since the early 1970s, from a total production of 3.3 million tons to 1.3 million tons in 2013. Horse mackerel and hake represent the most important species in terms of landings, with 25 and 22%, respectively. Stocks of both deep-water hake off South Africa and shallow-water Cape hake off Namibia have recovered to biologically sustainable levels as a consequence of good recruitment and strict management measures introduced since 2006. Southern African pilchard and anchovy stocks have improved and were categorised as fully fished in

2013. Whitehead's round herring is not fully fished. However, the condition of Cunene horse mackerel remained overfished in 2013. The condition of the perlemoen/abalone stock, targeted heavily by illegal fishing, has deteriorated and remains overfished.

Trends and future dynamics: Marine and coastal ecosystems face a similar range of threats as terrestrial systems, including overharvesting, climate change, pollution and invasive species. According to Sink *et al.* (2011), fisheries remain the biggest threat in South African coastal systems, while invasive species and climate change are emerging as threats to these systems. As climate warms, temperate communities are declining and tropical communities are increasing as these communities expand into areas formerly dominated by warm temperate species. On the eastern coast, (Lloyd *et al.*, 2012) recorded a decline in temperate species and an increase in tropical species, associated with warming sea temperatures. On the shallow Aghulas bank, several species of endemic seabreams and sciaenid's have been severely over-exploited, whereas warm water corals have been well protected. At the same time, cold water kelps and associated fauna are also penetrating the warm temperate zone (Bolton *et al.*, 2012). Habitat loss will lead to declines in marine species on which many coastal communities depend for food and employment.

3.4.5.2.4. Deep sea

Status and trends: Offshore areas are important habitat for many threatened seabirds, turtles and deep water fish, but most offshore habitats remain unprotected and poorly studied (Sink *et al.*, 2011). Seamounts and other complex, raised seabed features in the open ocean are often hotspots of biological diversity and production. Some attract concentrations of commercially-important pelagic fish, such as tuna, and concentrations of animals such as cetaceans, seabirds, sharks and pinnipeds. Seamounts also host deep-water fish species, such as orange or alfonsino that are highly attractive to commercial operator. The unsustainable nature of deep-sea fisheries and their impacts on seabed life raised concerns amongst the international community. One approach, adopted by the deep-sea fishing industry in some regions was to voluntarily close areas of the deep sea to trawling where they suspected there were concentrations of vulnerable marine ecosystems as a result of high levels of by-catch of corals and other habitat-forming species. Another approach was to try and estimate the distribution of vulnerable marine ecosystems like cold-water coral reefs through habitat suitability modelling and then to feed this information into spatial management of deep-sea fisheries to prevent impacts. Artisanal fisheries in the Indian Ocean are critical for the livelihoods and food security of the populations of coastal States in the region, particularly island nations such as the Seychelles. The offshore fisheries of the western Indian Ocean are rich but countries within the region have been unable to develop the infrastructure to exploit these fisheries. As a result they have allowed the distant-water fishing fleets of developed countries to access fish resources through multilateral or bilateral agreements. Currently (as of July 2010), there is little or no information available for the assessment of the impacts of deep-sea fishing in high-seas areas of the Indian Ocean on populations of target or bycatch species.

Future dynamics: A systematic approach to conservation planning and management has been applied in some terrestrial and coastal areas to maintain ecosystem health and guide sustainable use, but governance of high seas areas is currently weak (Ban *et al.*, 2014). The recent Phakisa initiative aims to establish 22 offshore Marine Protected Areas in the South African Economic Exclusion Zone.

3.5. Impact of biodiversity changes on nature's contribution to people

The contribution of nature to people is mostly recognised through different aspects of biodiversity, ecosystem processes and ecosystem functions that deliver services which are harnessed by humans for their well-being (Figure 3.21). Scientists and policymakers throughout the world recognise that the delivery of most ecosystem services is underpinned by biodiversity and ecological functions (MA, 2005; Díaz *et al.*, 2006; Egoh *et al.*, 2009; Maes *et al.*, 2012; Balvanera *et al.*, 2014; Harrison *et al.*, 2014; Figure 3.21). The link between biodiversity and ecosystems services can be traced from individual species or a group of species to ecological processes and ecosystem functions (Díaz *et al.*, 2007; Luck *et al.*, 2009; Maes *et al.*, 2016). The relationship between biodiversity and ecosystem services is indeed complex with some services delivered by single species while others are delivered by either a combination of species, functional traits or habitat types (Figure 3.22).

In most cases, species abundance and richness are particularly important for provisioning services such as timber production, fish production and medical plants, while habitat extent and functional diversity or traits are important for regulatory services such as water purification and regulation (Harrison *et al.*, 2014; Figure 3.22). Although this link needs to be proven in different continents, the relationship is mostly the same for most services but the underlying biodiversity may be different.

Since the relationship between biodiversity and ecosystem services is mostly positive, decline in individual species that play a central role in the ecosystem may have serious consequences for ecological processes that underpin nature's contribution to human well-being (Schwartz *et al.*, 2000). Also, habitat degradation impacts both species and ecological functions. For example, losses in forest cover can result in loss of timber species as well as loss in litter cover, which is important for water infiltration. However, the most important biodiversity attribute that impacts ecosystem services is functional diversity as it mainly impacts on the underlying processes (Díaz *et al.*, 2006; Flynn, 2009; Harrison *et al.*, 2014). Areas identified as hotspots for biodiversity have also been shown to overlap with areas important for the provision of ecosystem services, with degradation in such areas, resulting in negative impacts in multiple ecosystem services (Naidoo *et al.*, 2008; Anderson *et al.*, 2009; Egoh *et al.*, 2009). Indeed, the complete impacts of biodiversity on ecosystem services are nonlinear and complex and yet fully understood (Costanza *et al.*, 2007).

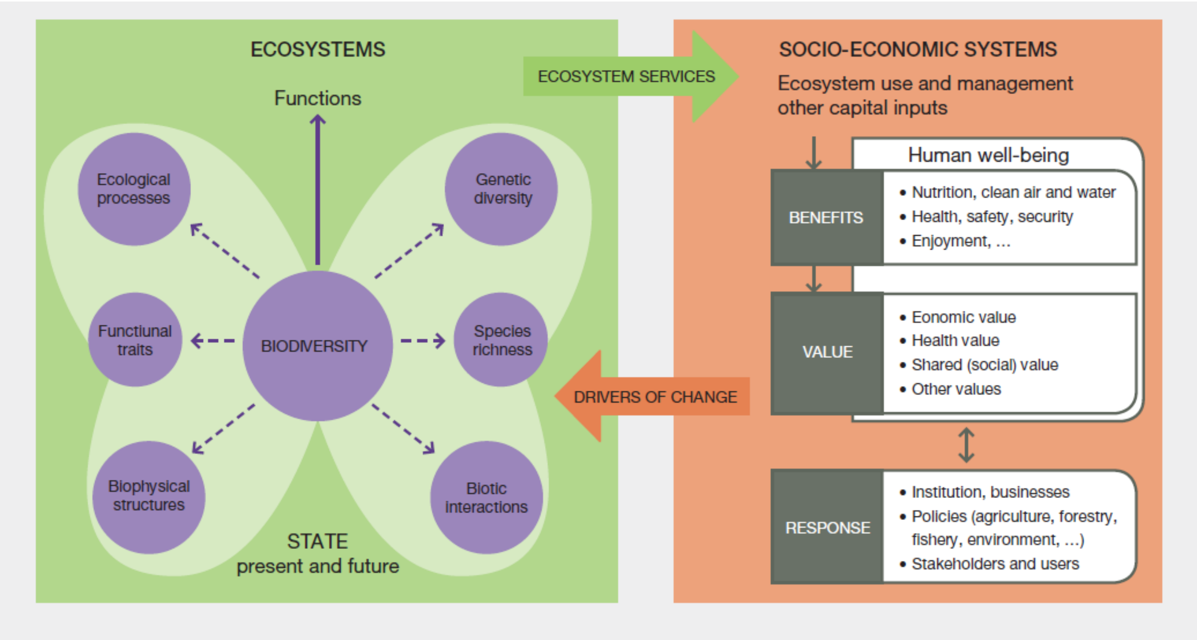


Figure 3.21: Links between nature and people. Source: Maes *et al.* (2016).

	SPECIES ABUNDANCE	SPECIES RICHNESS	SPECIES DIVERSITY	SPECIES SIZE/WEIGHT	MORTALITY RATE	FUNCTIONAL RICHNESS	BEHAVIOURAL TRAITS (POLLINATION)	BEHAVIOURAL TRAITS (BIOCONTROL)	COMMUNITY/HABITAT AREA	COMMUNITY/HABITAT STRUCTURE	PRIMARY PRODUCTION	ABOVEGROUND BIOMASS	BELOWGROUND BIOMASS	STEM DENSITY	COMMUNITY/HABITAT AGE	LITTER/CROP RESIDUE QUALITY
PROVISIONING SERVICES																
Timber production	↑	⬆↓														
Freshwater fishing	↑	↑		↑	↓						⬆					
Freshwater provision									↑↓					↓	↓	
REGULATING SERVICES																
Water purification		↑							⬆							
Water flow regulation									⬆	↑					↑	
Mass flow regulation		↑							↑	↑		↑	↑			
Atmospheric regulation		↑	↑	↑	↓					↑		↑	↑		↑	↑
Pest regulation	↑	↑			↑			↑	↑	↑						↑
Pollination	↑↓	⬆				↑										
CULTURAL SERVICES																
Recreation (species)	↑↓	↑	↑	↑												
Landscape aesthetics									↑	⬆						

⬆ strong positive relationship ↑ moderate relationship ↓ moderate negative relationship

Figure 3.22: Summary of positive and negative relationship between biodiversity and nature's contribution to people:↑ = positive relationship;↓ = negative impact. Source: Bugter *et al.* (2015).

The governance of nature also occurs at multiple scales which does not necessarily align with the beneficiaries and depends on several factors including the value of nature. However nature is governed, unsustainable use of nature due to gaps in governance will threaten the livelihood of the very same people who benefit from it. Therefore most of the key drivers affecting nature's contributions to humans are also those associated with the use of nature by humans through ecosystem services. For example, humans use grazing land for meat production but overgrazing is a serious threat to the continuous delivery of the services (Anderson *et al*., 2007). Other examples include overharvesting, overfishing and water extraction which are all listed as drivers hampering nature's contributions to people. The benefits of nature can only be achieved if use is sustainable through good governance across all scales.

3.6. Data Gaps

Research on nature's contribution to humans on regulatory and non-material contribution is largely lacking in most parts of Africa. Moreover most of the work in nature's contribution to people in regulating climate, water, soils and other regulatory services in mostly biased towards Southern Africa while material contributions such as non-forest timber products are biased towards areas with forest.

3.7. Conclusions and recommendations

Africa is very rich in biodiversity and is the last place on Earth with a largely number intact assemblage of mammalian megafauna. The continent has significant regional, subregional and national variations in biodiversity that reflect climatic and physical differences, as well as its long and varied history of human interactions with the environment. Africa's natural richness coupled with the wealth of indigenous and local knowledge on the continent, is central to, and constitutes a strategic asset for, the pursuit of sustainable development. Africa has diverse forests, woodlands, savannas, grasslands, arid zones, deserts, wetlands, inland surface waters and freshwater bodies like rivers, lakes and estuaries and the continent is surrounded by six large marine ecosystems. Most, if not all, terrestrial ecosystems in Africa have already experienced major biodiversity losses in the past 30 years, which has negative impacts nature's contribution to people. Unfortunately, unless major policy interventions are implemented, the prospect is that this trend will continue in the future. Africa's highly diverse terrestrial ecosystems are threatened by the land-use change (land conversion to agriculture, deforestation, habitat fragmentation) and climate change.

Freshwater biodiversity in Africa is under severe pressure with the majority of threatened species are found in areas with high levels of development and demand on water resources, mainly along the Mediterranean and Atlantic coasts of Morocco, Algeria and Tunisia, in Upper and Lower Guinea, southern and eastern South Africa and in the Great lakes in eastern Africa. Much of Africa's marine and coastal biodiversity is also threatened. The wide continental shelf along the northwest coast of Africa, mangrove forests of West and East Africa and adjacent islands, provide diverse habitats that support high levels of biodiversity of fish and invertebrate species. The Red Sea has a high degree of endemism and is an important repository of marine biodiversity. With overexploitation, habitat degradation and loss, acidification, pollution from land-based sources, invasive alien species and sea level rise, highly valuable ecosystem services are being threatened. Current losses of genetic biodiversity due to climate changes and unsustainable resource exploitation in Africa are restricting future management and development options and threaten the livelihoods of many African communities.

However, Healthy ecosystems can reduce socioeconomic vulnerability by supporting well-being. Healthy ecosystems are conserved social-ecological systems and a number of them are managed by local and indigenous communities. Africa has a vast amount of undocumented ILK that would enhance our understanding of biodiversity and ecosystems status and trends. ILK of the status and trends of biodiversity may be especially critical in the African region because of the relative dearth of scientific cultural diversity studies relative to other regions. The environmental knowledge held by indigenous people can lead to the discovery of new species and populations and can enhance our understanding of status and trends of species and ecosystems, particularly those that contribute to human livelihoods and well-being. The role of protected areas and new conservation strategies and tools such as the Management Effectiveness Tracking Tool are increasingly useful in managing current unprecedented rates of biodiversity loss. The extent of protected areas in Africa has almost doubled in the last decades; protected areas now cover 14% of Africa's terrestrial area and 2.5% marine. Effectiveness of protected areas is poor in many areas due to a combination of factors, such as: climate change, overexploitation (over-hunting, logging, livestock herding), civil conflicts, and encroachment from local populations to sustain their livelihoods, and inadequate park design and administration.

3.8. References

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Chapter 4: Direct and indirect drivers of change in biodiversity and nature's contributions to people

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Executive Summary

Africa's biodiversity and ecosystems are amongst the most vulnerable to climate change, with severe impacts already experienced on water availability and food production, thus affecting nature's contributions to people *(well established)*. This in turn is having a profound negative impact on Africa's ability to achieve sustainable development and will continue to do so unless mitigation measures are undertaken. Human-induced climate change is a major driver of biodiversity loss, changes in ecosystem structure and function and the ability of ecosystems to supply nature's contributions to people. Both the extent of climate change and the degree to which it impacts biodiversity and the supply nature's contributions to people are highly variable within and between Africa's subregions. In addition, temperatures in the continent are expected to rise faster than the global average with some areas warming at close to double the global mean. Future rainfall projections are less certain, although rainfall variability is projected to increase over most areas with most models suggesting fewer, but heavier rainfall and increased flooding events. Yet, many areas in Africa are predicted to become drier, despite the global increase in mean annual precipitation {4.2.2.1.2, 4.2.2.1.3}.

Africa's population is projected to grow from the current 1 billion to nearly 6 billion by 2100, putting severe pressure on the continent's biodiversity and the ability to provide nature's contribution to people. Africa is also one of the most rapidly urbanising continents, driving changes in biodiversity associated to land-use change due to increased demand for food, energy, water, infrastructure development and other services *(well established)*. Urban communities are producing large quantities of solid and other wastes that are leading to environmental pollution *(well established)*. Rapid population growth, urbanisation and the resultant demand for resources are driving land-use and land-cover change in Africa, leading to loss of the land's capacity to sustain biodiversity and provide nature's contributions to people *(well established)*. Conversion of forest and rangelands for agriculture, mining and urban development, among others, has led to habitat loss, degradation of catchment areas and soil erosion leading to loss of biodiversity and livelihoods. The fragmentation that results from various land-uses contributes to biodiversity loss because many wildlife species are migratory and conservation areas do not provide sufficient habitat and connectivity, especially for vulnerable species with narrow ecological niches *(well established)* {4.4.4}.

The spread of invasive alien species in terrestrial and aquatic ecosystems is rapidly increasing in Africa with impacts on native species, rural livelihoods and production systems *(established)*. These impacts affect major economic sectors including agriculture, forestry, tourism, fisheries and others. The introduction of most invasive alien species occurs for various reasons including enhanced supply of goods and services to people (e.g., timber, food, medicinal and manufacturing purposes), but the proliferation of invasive alien species into natural systems is rapid and complex. The management and control of invasive alien species in Africa remains a challenge. A few countries have quantified the extent and the impact of invasive alien species on biodiversity and nature's contributions to people. However, challenges remain with understanding rates of spread, complex interactions with disturbance regimes and natural climate variability. Climate change is set to exacerbate the impact of invasive alien species in many African ecosystems *(established, but incomplete)* {4.2.2.3}.

Overharvesting and poaching of vulnerable species (rhino and elephant poaching; lion hunting, abalone and other illegal fishing; illegal logging; charcoal production and bushmeat harvesting) is driven by commercialisation of biodiversity with national, urban and foreign markets imposing negative impacts on biodiversity and nature's contributions to people *(well established)*. The proliferation of unsustainable harvesting of wildlife is exacerbating the impacts of habitat loss. Rhino and elephant poaching for horn and ivory, respectively, have led to substantial decline in the populations of these keystone species in many subregions in Africa {4.2.2.2.3}. Global markets and demand for wildlife products as well as local pressure from privately owned commercial wildlife ranches have severely challenged national policies because of the prevailing poverty, illicit trade and the high value of these products in the global markets. Illicit trade in wildlife is many cases linked with international criminal gangs involved in the drug trade, human trafficking and terrorism *(well established)* {4.2.2.2}.

Soil, water and air pollution present major challenges and cause biodiversity and undermine nature's contributions to people and good quality of life in general. Pollution has led to degradation of ecosystem functions and services in Africa *(well established)*. Population growth and urbanisation has created a greater demand for food production, energy and water but also increased the amount of wastes associated with provision of various services that rapidly growing urban populations demand. The expansion of agriculture, extractive (mining) and manufacturing industries, transport and building sectors and urban settlements is not congruent with existing effluent and waste-management strategies. A large number of chemicals and pollutants including prohibited Persistent Organic Pollutants such as Dichlorodiphenyltrichloroethane (DDT) continue to be marketed and used in the region with dire consequences for human health *(well established)* {4.2.2.4}.

Fires burn significant amounts of biomass across Africa every year, with more than half of global fires occurring in the continent of Africa. These is to a large extent being natural fires. However, the alteration of fire frequency and intensity impacts on biodiversity and nature's contributions to people *(well established)*. Many landscapes of West, East and Southern Africa, especially in grasslands, fynbos and savannas, are fire-dependent ecosystems and burn frequently, especially during the dry season. Eliminating fire from these systems is detrimental to biodiversity. North Africa, and parts of east and southern Africa are semi-arid to arid and not prone to fire due to very low biomass to sustain fire. The equatorial region of Central Africa is too moist to support fires. Emissions from Africa's fires can be largely considered as climate-neutral as the burned biomass is replaced over the next few seasons. Climate change may, however change the nature of fires and the extent of areas burnt {4.2.1.2}.

Changes in land ownership and an increase in land acquisition (land grabs) to meet local, national and global food and renewable energy demand are driving changes in nature and nature's contributions to people. Land ownership is shifting from small-holder farmers to large-scale commercial farming and land-use (or the focus of production systems) is shifting from subsistence agriculture to supply a growing international biofuels industry, influenced by policies in rich nations *(established but incomplete)*. This is contributing to land conversion as critical ecosystems including wetlands, rangelands and forests are being converted into agricultural land for food or energy markets *(well established)*. There are also trade-offs in the use of land for the production and supply of food, water, energy and other land-uses such as mining and development of human settlements (food-water-energy nexus) *(well established)* {4.4.1}.

Sustainable development thrives best in an environment of good governance, peace and security whereas armed conflict has substantial costs in human and material terms, hinders production, damages infrastructure, prevents the reliable delivery of social services to communities *(well established)*. Organised criminal networks carry out environmental crimes (poaching, illegal wildlife trade, illegal trade of timber and non-timber forest products) across borders and affect national economies, security and threaten sovereignty of some countries *(well established)*. Environmental crimes undermine the livelihoods of natural resource dependent communities, damage the health of the ecosystems they depend on, and restrict potential investment in development of affected areas. Terrorists and rebel groups participate in environmental crimes in order to fund their illegal activities *(well established)*. Insecurity leads to localized biodiversity loss, especially diversity of wild fauna and, undermines Africa's conservation legacy and livelihoods of resource-dependent communities *(well established)* {4.2.2.2.3, 4.4.1.2}.

Many communities in Africa are highly depended on natural resource-based livelihoods and are vulnerable to rapid societal changes in policies that affect their indigenous and local ways of livelihood *(well established)*. Rapid changes (observable climate change, rapid urbanisation, rapid land transformation, changes in production systems) are strongly linked to the vulnerability of indigenous and local peoples and communities. There may be unintended consequences in that indigenous and local knowledge may be a barrier to exploring alternative development options. This is due to the fact that indigenous and local peoples do not easily adapt to rapid changes, such as those due to climate change, which necessitate changes in preferred crops because of changes in crop suitability maps. Indigenous and local knowledge works in small-scale agriculture setting but rapid changes to large-scale intensified agriculture may undermine indigenous and local knowledge methods *(established)* {4.4.4.1, 4.4.7}.

4.1. Introduction

This chapter deals with direct drivers (both natural and anthropogenic) and indirect drivers of change, as well as interactions between direct natural and anthropogenic drivers of change. Chapter 3 described the current status and trends of biodiversity and ecosystems (nature) and nature's contributions to people across the continent of Africa. The focus of this chapter is on key drivers that influence the status and trends of biodiversity, ecosystems and nature's contributions to people identified in Chapters 2 and 3, with a special focus on those that have the highest impact on the unique natural resources and nature's contributions to the people of Africa. Chapter 4 therefore follows up on the trends and value of nature's contributions to people dealt with in previous chapters, with more in-depth focus on drivers of change and their likely future dynamics. It is important to understand drivers of change, whether direct or indirect, in order to contribute to informed decision-making about managing the causes of negative changes in nature, nature's contributions to people and to good quality of life. Such information offers a range of scenarios and governance options for decision-makers, considered in Chapter 5 and Chapter 6, respectively. Both direct and indirect drivers of change constitute an essential part of the IPBES conceptual framework, and will be introduced in this section and elaborated on in sub-sections detailing the type of effects drivers have on nature, nature's contributions to people and to the quality of life of the peoples of the African continent (Díaz *et al.*, 2015; Figure 1.1 in Chapter 1).

Africa is endowed with abundant natural capital supporting livelihoods through a variety of nature's contributions to people (McNaughton *et al.*, 1988; McClanahan *et al.*, 1996; Tidjani *et al.*, 2009; Scholes *et al.*, 2011; Archibald *et al.*, 2013; Pascual *et al.*, 2017). These encompass a wide range of ecosystems ranging from deserts to tropical rainforests; Afro-alpine to marine habitats; rivers, wetlands, grassland and savanna ecosystems amongst others. Africa's rich biological and cultural diversity is an asset for the people of the continent. Interactions between diverse climates, vegetation types and topography create unique ecoregions and confer immense biological (floral, faunal and microorganism) diversity on the continent (Dixon *et al.*, 2003; Merbold *et al.*, 2009). Africa's biodiversity has underpinned its development for generations, as described in Chapter 1. Yet, the continent remains one of the poorest in the world. Instead of bringing prosperity, Africa's resources have been a source of many conflicts brought about by the scramble for her resources. Africa's biodiversity and ecosystems face a variety of threats (Figures 4.22, 4.23, & 4.26 on Threats and Pressures).

Future trajectories for the continent suggest that Africa will continue to experience high population growth due to high fertility rates. Rapid urbanisation will also continue for the next half-century due to rural-urban migration (Young *et al.*, 2009; Freire *et al.*, 2014), with a projected 54% of Africa's population living in urban areas by 2030 (Hay *et al.*, 2005). These migrations are leading to massive and rapid infrastructure developments including roads, sewage, piped water and energy supply to support human settlements. Unlike indigenous and local or rural populations, which tend to be less dependent on centralized infrastructure, urban areas require planning and development of infrastructure and facilities to enable acceptable living conditions. Even though some threats and pressures from these are localized, others such as railways, motorways, overhead transmission lines and oil pipelines tend to operate at regional scales.

Direct drivers refer to those drivers, pressures and threats that have an explicit impact (negative or positive) on biodiversity, ecosystems and the nature's contributions to people and can either be natural or anthropogenic. The natural direct drivers discussed in this chapter include climatic factors, natural fires as a driver of ecosystem change, diseases and pests (zoonotic and human diseases) and natural disasters (tsunamis, volcanos, earthquakes). The anthropogenic direct drivers highlighted include land-use and land-cover change (deforestation and loss of rangeland), overexploitation (overgrazing, overharvesting, overfishing), invasive alien species, and pollution (soil, water, air). We have also considered positive drivers such as protected areas, the role of multilateral environmental agreements, and sustainable land management.

It is important to note that direct natural drivers of change are natural phenomena that occur without human intervention, although the impact or effect on people may be exacerbated by human activity as in the case of impacts of flooding on human settlements built in floodplains. Anthropogenic drivers, on the other hand, are purely an outcome of human activities, such as clearing of land for housing development or agriculture. Such human activities have a direct effect on biodiversity and ecosystems and therefore directly affect nature's contributions to people. The effect may be either positive or negative, depending on the benefit people seek to derive from nature. Generally, there are trade-offs that often result because the exploitation of one resource may improve quality of life for some people while diminishing nature's contributions and quality of life for others. The effects or general impact of these direct drivers of change can be identified, measured and monitored (Nelson *et al.*, 2005; Ash *et al.*, 2008; Díaz *et al.*, 2015). However, there are interactions between natural direct drivers and anthropogenic direct drivers that can be clearly linked to changes in biodiversity and nature's contributions to people. Climate change is an obvious example of this combined influence of both natural and anthropogenic drivers of change because although climate is a natural phenomenon, it is now widely accepted that increases in greenhouse gas emissions linked to both industrial and post-industrial era, has led to higher rates of global warming. This has huge consequences for both natural and social-ecological systems in Africa.

Indirect drivers of change, on the other hand, are drivers that cause alteration of the rate at which direct drivers impact biodiversity and nature's contributions to people (Nelson *et al.*, 2005). The decisions made by society, whether influenced by leaders in the public or private sector, and the influence of those decisions on human behaviour has major consequences for nature and nature's contributions to people. There are many examples where decision-making has led to poor outcomes for nature and nature's contributions to people, leading to declines in the quality of life of the people. The consequences are usually severe for vulnerable communities, particularly rural populations and the poor, who depend directly on nature's contributions to people for essentials such as food, timber and water. In this chapter we discuss many drivers of change, but we also address in particular those drivers that may result in positive changes in nature and nature's contributions to people. Here, we consider the following drivers: changes in economic and environmental policies, economic systems, population growth, migration and urbanisation, technology developments and application, insecurity and corruption, and cultural practices and spirituality.

This chapter takes into consideration that the effects of the different drivers of change vary across Africa's subregions. Care has thus been taken to ensure that cases of unique subregional or ecosystem (terrestrial, freshwater and coastal/marine) differences among the drivers have been taken into account. This chapter, therefore, provides a critical analysis of how various direct and indirect drivers of change currently influence change in nature and nature's contributions to people, and ultimately human well-being or the quality of life for the people of Africa. Such an analysis is aided by the use of case studies and infographics. An attempt has been made to link content presented in this chapter to other IPBES thematic assessments (such as those on scenarios and modelling and land degradation), which are also pertinent to the continent of Africa.

4.2. Direct drivers of biodiversity change and flow of ecosystem services

Direct drivers of biodiversity change and ecosystem service flows can be discussed as natural occurrences or anthropogenic ones, taking into consideration that frequent interactions occur between the drivers. All natural systems have a degree of resilience to change - of particular concern is when the drivers of change are of sufficient severity to exceed thresholds leading to a permanent change in the systems dynamics, or in the case of biodiversity to the local or global extinction of species (Holling, 1973; Folke *et al*., 2010). Direct drivers have an explicit effect on ecosystem dynamics and processes and are known to cause direct physical change that may be identified and monitored (Nelson *et al.*, 2005; Ash *et al.*, 2008). In African ecosystems there are natural disturbances such as drought or fire which occur in most ecosystems, but with location-specific return intervals and severity. These are important for maintaining the integrity and resilience of the ecosystems over the long-term, but can negatively impact on flows of nature's contributions to people over the short-term. Superimposed on these natural disturbances are a host of anthropogenic drivers of change that can have devastating impacts on the natural environment either on their own or through interactions with the natural disturbances. For instance humans can change the frequency or seasonal timing of fire and climate change can alter the frequency and intensity of droughts (Figure 4.1). In the section below, natural and anthropogenic direct drivers are discussed.

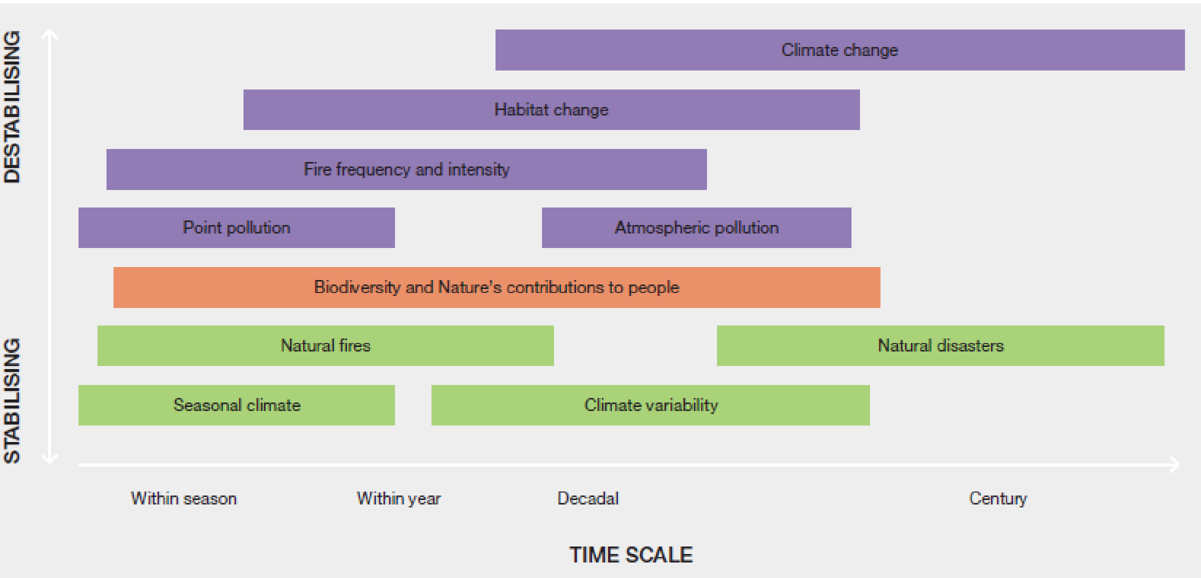


Figure 4.1: The time periods over which different types of disturbances either help stabilize and build resilience in natural biodiversity and the nature's contributions to people that it provides, or leads to change in the biodiversity and nature's contributions to people.

4.2.1. Natural direct drivers

African biodiversity and ecosystems have evolved under the influence of a number of natural disturbance regimes, and when viewed over sufficient time and space, are to a large extent resilient to natural drivers of change. In fact, many disturbances such as fire, are important for maintaining biodiversity. However, at a local level or short time span, natural drivers can have profound impacts on biodiversity and the flow of nature's contributions to people. As will be discussed later, the interplay between natural and anthropogenic drivers can enhance these impacts.

The long-term natural drivers of change are now known to be paced by orbital forcing, and display dominant periodicities at 100,000, 41,000 and 23,000 years, which are related to the earth's eccentricity, tilt and precession, respectively. They subtly modulate the incoming radiation from the sun at the surface of the earth, but their effects are amplified by earth-intrinsic factors such as the volume and extent of sea and land ice, vegetation and soil cover, ocean and atmospheric circulation, and variations in cloud cover and type, to an extent where the resultant climatic and environmental changes are large enough to be etched visibly on the geological record (O'Hare *et al.*, 2005). Studies of long-term changes in vegetation indicate that there is a close and dynamical relationship between such changes and variations in temperature, precipitation and atmospheric CO_2 concentrations (Olago, 2001), and the present day distribution of vegetation in Africa largely reflects the continent's precipitation patterns. Large ecosystems may buffer climate signals of small amplitude, but vegetation response time to climate change is slow (Ssemmanda *et al.*, 2002; Marchant *et al.*, 2004).

4.2.1.1. Natural climate variability and weather patterns

African biodiversity has evolved in an environment with a naturally high level of climate variability, and, as such biodiversity and ecosystem services are adapted to, and dependent on climatic zones and their associated variability (Dixon *et al.*, 2003; Merbold *et al.*, 2009). Africa's biodiversity is a consequence of past climatic regimes (Letten *et al.*, 2013). The vast savannas, grasslands and deserts have strong seasonality of rainfall. In the northern and southern tips of the continent, there is a Mediterranean climate with hot and dry summers and characterized by winter rainfall. The tropical rainforests of Central Africa and the southern coast of Southern Africa tend to have all year rainfall. Rainfall patterns through much of the continent are linked to cyclic fluctuations in sea surface temperature, with the El Niño Southern Oscillation causing cycles of wet and dry years in eastern and southern Africa (Figures 4.2, 4.3, and 4.4). The coefficient of variance of rainfall is negatively correlated with rainfall and the arid areas are therefore the most prone to intense droughts (Tyson, 1986; Plisnier *et al.*, 2000; Davey *et al.*, 2014). Given that arid areas are already at the margins of agricultural productivity, these droughts can have severe human consequence. Droughts are part of the natural cycle and current biodiversity patterns are adapted to them. However, human pressure caused by increased reliance on the natural environment during periods of drought can lead to degradation of these ecosystems (Behnke *et al.*, 2016).

The Sahelian drought and resultant degradation of the 1970s to 1990s was initially referred to as desertification (Behnke *et al.*, 2016). At the time this was attributed to increasing population and poor land management, which clearly placed increased pressures on the system. New and extensive evidence shows that this degradation coincided with a prolonged dry period, the causes of which are still poorly understood but may be related to global sulfate pollution in the northern hemisphere (Hwang *et al.*, 2013) or Interdecadal Pacific Oscillations (Villamayor *et al.*, 2015; Figure 4.4). More recent increases in rainfall are largely responsible for the greening of the area as detected from satellite imagery (UNEP, 2012). Long-term climatic fluctuations rather than human-induced desertification, therefore, seem to be the primary cause of the Sahelian degradation of the 1970s and 1990s (Behnke *et al.*, 2016).

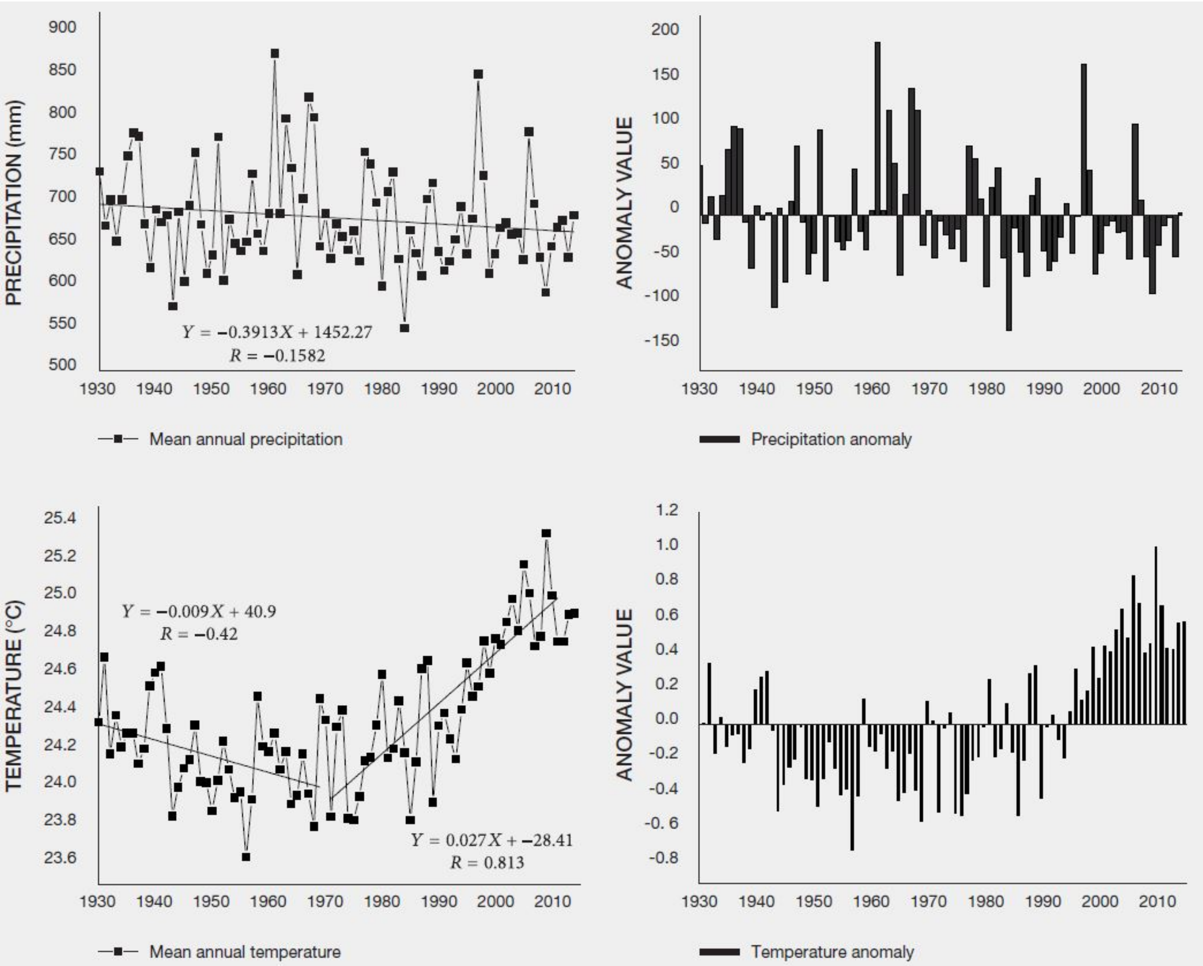


Figure 4.2: Long-term precipitation trend and anomaly (1930–2014) in the Horn of Africa. Source: Ghebrezgabher *et al*. (2016).

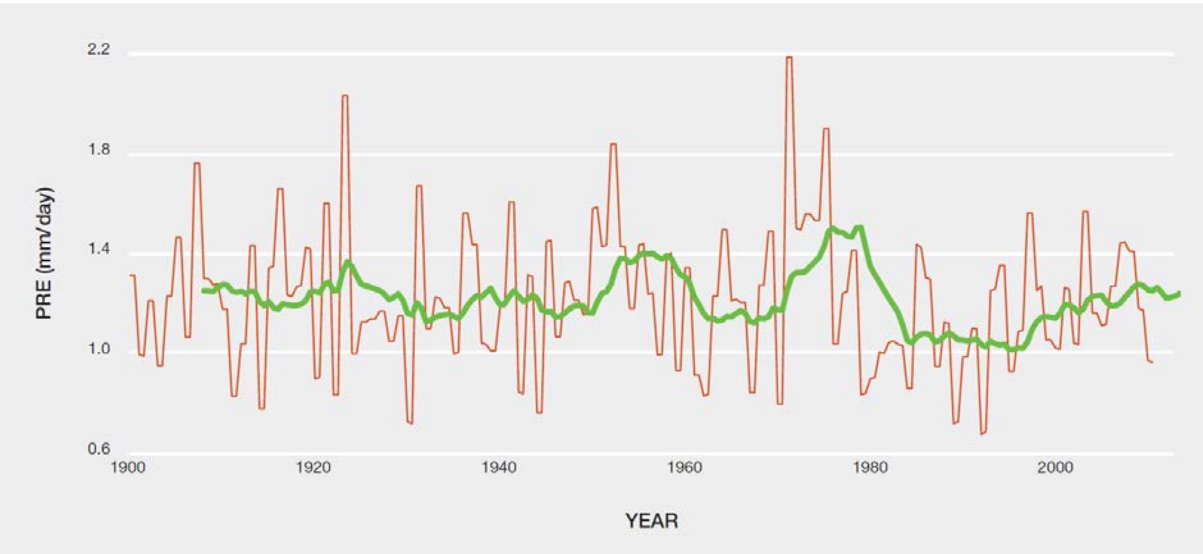


Figure 4.3: Annual rainfall variability over the Semi-arid regions of Southern Africa. Source: New (2015).

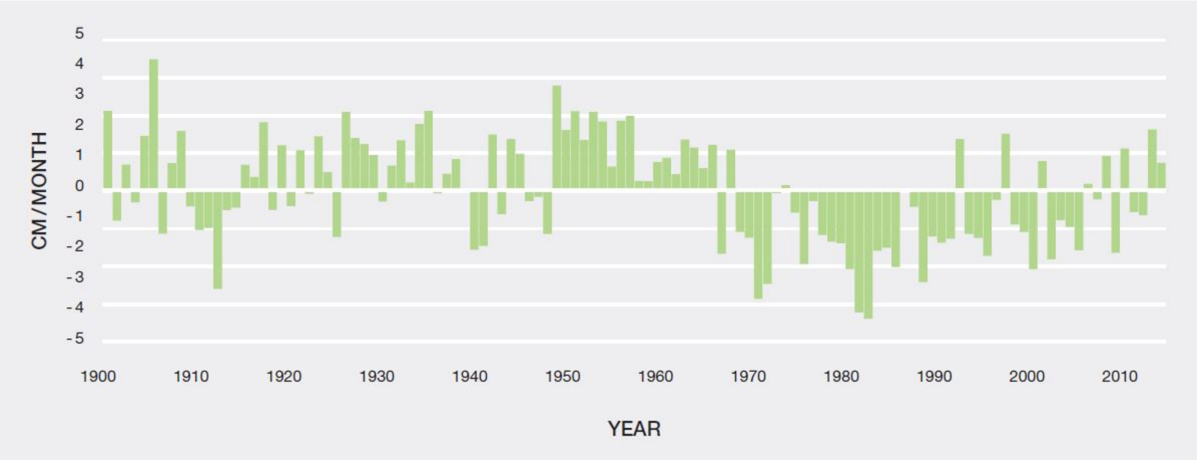


Figure 4.4: Sahel rainfall from 1900 to 2016 averaged over June, July, August, September, and October. A prolonged wet period from 1915 to 1970 was followed by a dry period from 1970 to 2016. The region appears to again be entering a wet period. Source: https://doi.org/10.6069/H5MW2F2Q

4.2.1.2. Fire as driver of ecosystem change

In Africa, both natural fires and human-ignited fires play an important role in shaping the structure and composition of various ecosystems, except where biomass is too low to carry a fire or where the area is too wet to burn. Fire is also seen as a management tool for manipulating vegetation for various management objectives such as influencing the distribution of animals, setting fire belts and for burning moribund vegetation. Certain vegetation types such as the grasslands, savanna and fynbos are dependent on fire for their optimal ecological function. In these vegetation types suppression of fire has major negative consequences for biodiversity with gradual negative impacts on ecosystem services. Globally, fire activity peaks at intermediate productivity, and this is also apparent in Africa: in arid ecosystems there is seldom sufficient fuel for fires, and in wet, more productive systems there is plenty of fuel, but it is usually too wet to be easily flammable (Figure 4.5). Because systems with a lot of fire have a biota that has evolved with these fire regimes, the relationships between biodiversity and fire are not simple.

It has been suggested that it is the variability in fire events (different fire sizes, fire intensities, fire return times) that is key for maintaining high biodiversity (Martin *et al.*, 1992), and there is evidence in Africa that bird and mammal species richness responds positively to "pyrodiversity" (Hempson *et al.*, 2017)– especially in wet ecosystems where fire can dramatically influence habitat structure (altering the size and cover of trees and the amount of grass), and where variability in fire can result in a variety of habitats. More targeted use of fire has also been suggested for preventing particular undesirable landscape change/biodiversity loss. Fire can be a management tool, coupled with browsing, to maintain open grassy ecosystems and prevent increases in woody vegetation in grasslands (Trollope *et al.*, 1989) in these instances, targeted intense and/or frequent fires are necessary. In contrast, burning cooler, less frequent fires in Miombo woodlands can preserve woodland resources and increase ecosystem services (Ryan *et al.*, 2016).

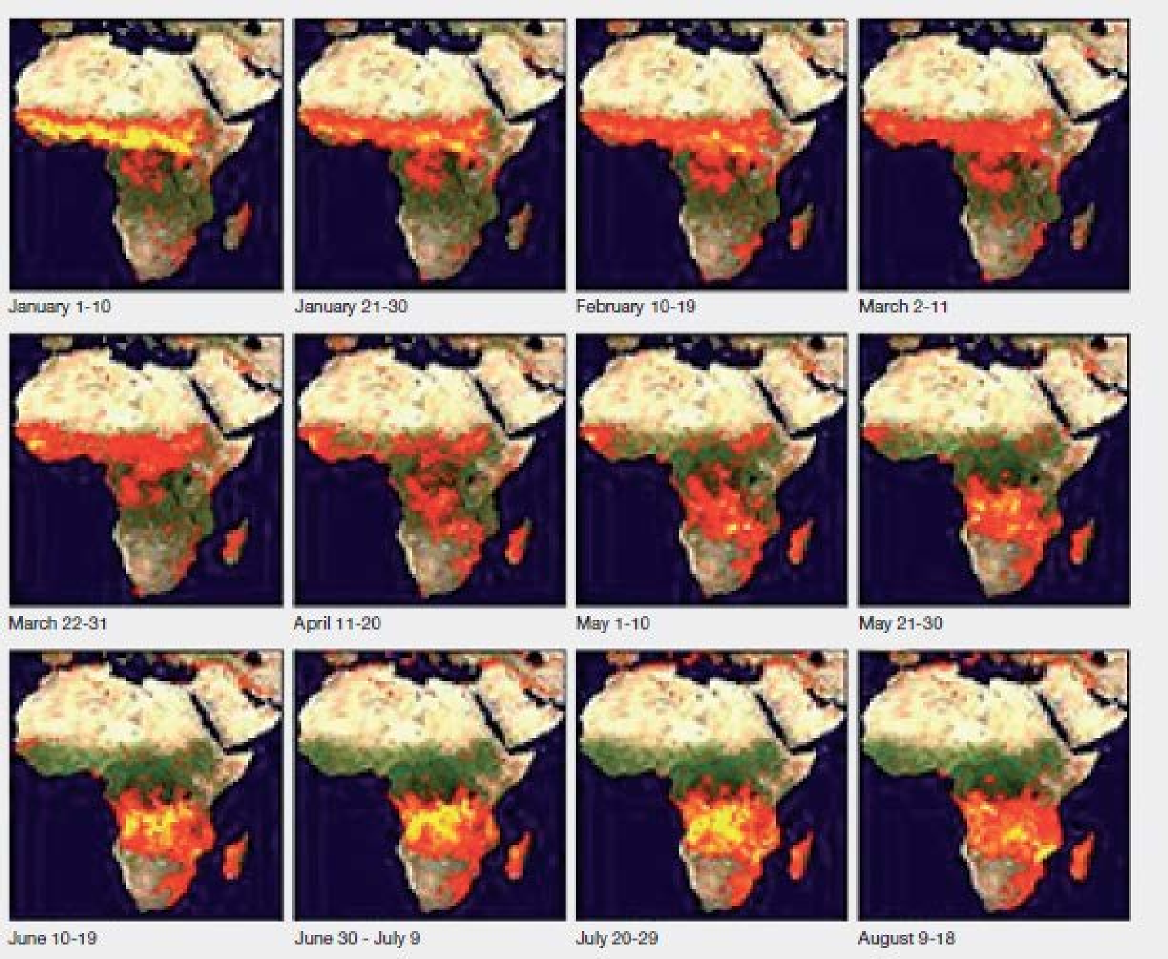


Figure 4.5: The fire season appears as a distinct wave as it spreads through Africa. It peaks in January in West Africa (the northern hemisphere dry season), and in southern Africa in August (southern hemisphere dry season). Source: NASA MODIS Active Fire product.

Both human activities and changing climates are likely to impact fire, with associated impacts on biodiversity and ecosystem services (Andela *et al.*, 2014). Because fire peaks at intermediate productivities we expect different responses to climate change in arid and mesic systems: high-temperature environments will make the wet end of the continuum more likely to burn, but could also further reduce fuel loads in arid systems, and result in less fire in these regions. Moreover, increased woody cover can suppress fire. In general increased human populations leads to more frequent, but smaller fires than in natural systems (Archibald *et al.*, 2013), with far less area burned as croplands and rangelands expand (Andela *et al.*, 2014). It has been shown in Africa and elsewhere that people can buffer ecosystems from climate-induced extreme fire events, because they burn over a wider range of weather conditions, and because their land-use activities break up the fuel landscape. These activities can over-ride climate drivers of large fires. Unexpected fire may have short-term but devastating effects on forage resources and dry winter crops, affecting the livelihoods of local communities. Accumulated biomass due to fire suppression has never seldom been a problem in Africa, except in the fynbos biome.

Fires burn significant amounts of biomass across Africa every year, with more than half of global fires burn on the continent of Africa (van der Werf *et al.*, 2010; Scholes *et al.*, 2011; Archibald *et al.*, 2013). Yet, the distribution of fire across the continent is not homogenous. North Africa, which tends to be semi-arid to arid (mostly covered by the Sahara desert), is not prone to fire due to very low biomass to sustain fire. Desert zones within Northern and western Africa are not affected by bush-fires because of poor vegetation cover. On the other hand, grazing lands in semiarid zones growing on sandy soils are highly subjected to bush-fires accidentally provoked by human at the beginning of dry seasons. Their impacts are harmful to the environment through the reduction of forage availability as well as decrease of biodiversity, and at social level through the degradation of food security for livestock and poverty increase in communities (Abdou, 2012). In Niger, between 1990 and 2000, 861 cases of bush-fires were reported with effect on more than 2,119,604 hectares (Ichoua, 2001).

Parts of East Africa and adjacent islands, especially in the Horn of Africa, as well as South-Western parts of Southern Africa are also less prone to fires due to lack of vegetation to support fires. The vegetation is too sparse and shrubby and fire plays a very insignificant role in management of these landscapes (Archibald *et al.*, 2013; Figure 4.6). The equatorial region of Central Africa is also not prone to fire despite large amounts of biomass. This is mainly due to wet conditions that prevail in this region throughout the year. In contrast, many parts of West Africa, East Africa and adjacent islands, and Southern Africa, especially in grasslands and savannas, are prone to burning especially during the early dry season when the grass is dry and other conditions for fire (whether natural or human-ignited) prevail. These include high temperatures and humidity and relatively high speeds of dry winds that cause rapid spread of fires. Sahelian savannas, grasslands and some shrubland ecosystems, many of them being fire driven ecosystems, tend to burn more frequently and with greater intensity during the dry season. These fires, many of them ignited by humans, have great impacts on biodiversity and ecosystem services.

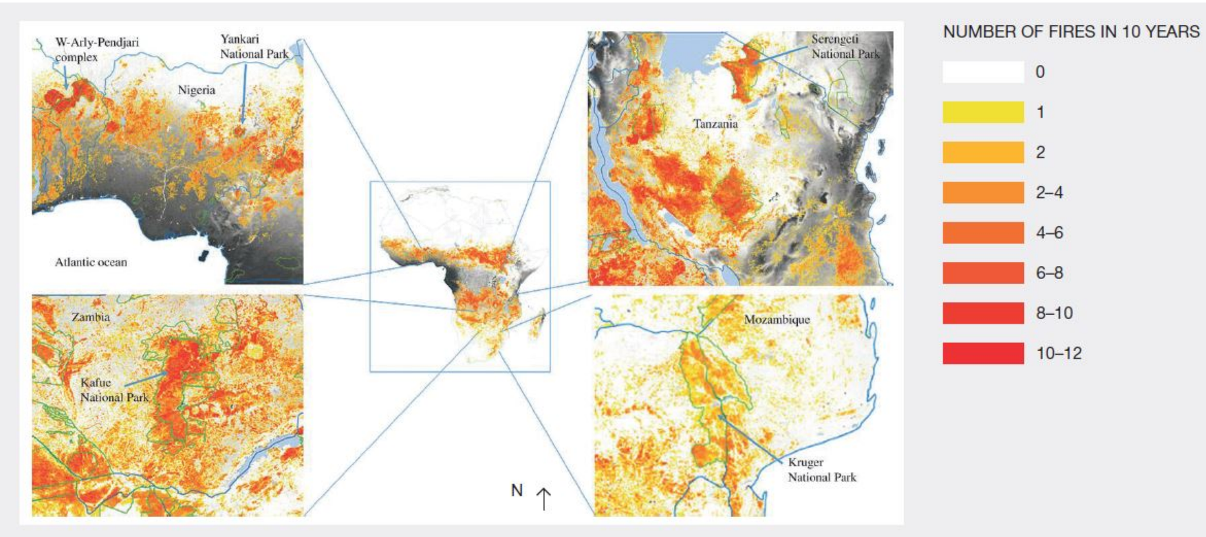


Figure 4.6: Frequency of fire in Africa for the period 2000 to 2010. Dividing the number of times a pixel was detected as having burned into 10 gives the approximate fire return time, in years. Source: Archibald (2016).

4.2.1.3. Diseases and Pests (zoonotic diseases, human diseases)

Diseases and pests impact the ecosystem health and integrity of the African terrestrial, aquatic and agroecosystems in ways ranging from economics (loss of output, income and investments) to ecological (e.g., loss of populations and species diversity) (Table 4.1). These impacts are greatly influenced by human encroachment of wildlife habitats, agricultural intensification, and urbanisation (Daszak *et al.*, 2000) as well as changes in global weather patterns (Hernández-Delgado, 2015). Loss of biodiversity commonly leads to increased occurrence of emerging infectious diseases including zoonotic diseases (Keesing *et al.*, 2010) thus compromising key nature's contributions to people offered by biodiversity. Historically, the African continent has been afflicted by a number of notable emerging infectious diseases which are newly discovered diseases, diseases that have changed pathogenesis, diseases with increased geographic or host range (Anderson *et al.*, 2004). Among the plants, cassava mosaic virus (East African cassava mosaic virus-Uganda 3Svr (whitefly-transmitted begomovirus) and the fungal Karnal Burnt (*Tillentia indica*), are known to have seriously affected cassava in East Africa and wheat in South Africa, respectively (Anderson *et al.*, 2004; Box 4.1). Both domestic animals and wildlife have also been affected by the emerging infectious diseases. Notably rinderpest, rabies, trypanosomiasis, canine distemper, and anthrax which are domestic animal diseases and have been known to be transferred to wildlife due anthropogenic factors, with devastating consequences.

The canine distemper infected 85% of the lion population in Serengeti and eliminated one third of the population (Cleaveland *et al.*, 2000; Guiserix *et al.*, 2007) while Ebola killed 5,000 of the endangered and charismatic gorillas, and other non-human primates coinciding with a human outbreak of the Zairean strain of the virus (Bermejo *et al.*, 2006; Le Gouar *et al.*, 2009). The occurrence of and control measures instituted against trypanosomiasis in large parts of Africa impacts on biodiversity and restricts economic development (PATTEC, 2006). The disease caused by varied species of a protozoan, *Trypanosoma* spp, is transmitted by tsetse fly (*Glossina* spp), to humans, livestock and wildlife and occurs in more than 30 sub-Saharan African countries (Wamwiri *et al.*, 2016). The disease causes severe health burden among infected humans, limits productivity of livestock, leads to overstocking of livestock in disease-free zones and poses serious conflict on the choice of appropriate policy measures for its control (FAO, 2008; Selby *et al.*, 2013). For example, bush clearing is a strategy to control the vector of Trypanosomiasis (Rutto *et al.*, 2013) but also leads to destruction of wildlife habitat and environmental degradation. Tsetse and trypanosomiasis infestations have negative impact on wildlife health too, and can be a threat to the survival of some endangered species such as the rhino (Kenya Wildlife Service, 2012) while rinderpest can cause high deaths in the buffaloes, giraffes, and wildebeests. Foot-and-mouth disease is one of the major diseases affecting numerous species of cloven-hoofed wildlife and livestock, including buffalo, impala, cattle, sheep, goats and pigs. Understanding the epidemiology of Foot-and-mouth disease, including roles played by different hosts, is essential for improving disease control. The African buffalo (*Syncerus caffer*) is a reservoir for the Southern African Territories serotypes of Foot-and-mouth disease virus (Wekesa *et al.*, 2015). Foot-and-mouth disease has severely negative economic impacts because imports of meat and animals from affected countries are banned by disease-free countries to control the spread of Foot-and-mouth disease. Among amphibians, the panzoonotic Chytrid fungus (*Batrachochytrium dendrobatidis*) is widespread in Africa except in the West of Dahomey (Penner *et al.*, 2013). It causes hyperplasia and hyperkeratosis disrupting critical functions of the infected amphibian’s skin and leading to cardiac arrest (Voyles *et al.*, 2011).

Table 4.1: Economic impacts of pest diseases in Africa.

	Pest/disease	**Damage caused**	**Estimated losses from outbreaks or control**	**Country/region**	**Source**
Pests	African armyworm	Feeds on all types of cereal crops (e.g., corn, rice, wheat, millet and sorghum)	Cost of control: $10–$16/hectare Potential damage: $11–$15/hectare	All African countries	Wild, 2017
	Tsetse fly	Feeds on the blood of	Each year in Africa the tsetse fly causes	Sub-Saharan Africa	Shaw, 2009

		vertebrate animals	more than $4 billion in agriculture income losses, kills three million livestock and infects up to 75,000 people with trypanosomiasis, according to the United Nations		
	Insect and mite pests	Significant yield losses of agricultural crops	The economic crop losses caused by introduced arthropods in South Africa alone are estimated to be $1 billion/year	All African countries	Pimentel *et al.*, 2000
Diseases	Brucellosis	Serious alien livestock disease	Estimates are that brucellosis alone is causing losses amounting to $100 million/year	Sub-Saharan countries	Ducrotoy *et al.*, 2015
	Anthrax	Threat to both domestic and wild animals. It is only disease that must kill its host to propagate itself in the environment	In Namibia, millions of dollars (~ $27 million) are spent annually on surveillance in both wildlife and domestic animals	Currently occurs throughout Africa	Magwedere *et al.*, 2012
	Rinderpest		The total cost of the Pan African Rinderpest Campaign programme was estimated to be €51.6 million	Sub-Saharan Africa	Tambi *et al.*, 1999
	Wheat rusts	A fungal disease that affects wheat, barley and rye stems, leaves and grains	Annual losses of as much as $3 billion in Africa are possible due to wheat rust	East Africa, North Africa	Chaves *et al.*, 2013
	Bacterial wilt	Causes fruit to ripen prematurely,	Due to bacterial wilt, Uganda loses $299.6	Eastern Congo, Ethiopia, western Kenya,	Yuliar *et al.*, 2015

		which can wipe out up to 90% of a crop	million worth of bananas annually	Rwanda, northern Tanzania and Uganda	
	Foot and mouth disease	Livestock	Foot and mouth disease outbreaks in Africa causes losses of $1–5 billion/year	Africa	Knight-Jones *et al.*, 2013

A number of vectors (pests) play key roles in transmission of diseases between the domestic animals, wildlife and the humans. Disease vectors include insects, such as mosquitoes, ticks, and arachnids. As mentioned in Chapter 1 and 2, the rise of such diseases results from closer relationships among wildlife, domestic animals, and people, allowing more contact with diseased animals, organisms that carry and transmit a disease from one animal to another, and people. The rift valley fever, a haemorrhagic febrile viral zoonotic disease transmitted by Aedes, Culex and Anopheles mosquitoes is associated with abortion and perinatal death in the affected livestock and ruminant wildlife, and fatal haemorrhagic fever syndrome in humans (Evans *et al.*, 2008; Chevalier *et al.*, 2010; Boshra *et al.*, 2011). Outbreaks of rift valley fever coincide with conducive weather (wet) for breeding of the vector mosquitoes, mostly the Aedes and Culex, especially in the general low rainfall areas (Evans *et al.*, 2008). Severe outbreaks of the disease and fatalities in humans have been confined to northern and Africa (North and sub-Saharan Africa) so far, but potential for spread to southern Europe exists (Chevalier *et al.*, 2010).

4.2.1.4. Natural hazards and disasters

Box 4.1: Cassava mosaic and brown streak virus disease: A threat to food security in Africa

In about 15 African countries, over 4 million people live within areas of high cassava production. Often these are among the most remote and poorest rural areas. Cassava production continues to be threatened by the spread of cassava diseases with immediate and far-reaching impacts on food supply in the affected countries (commonly referred to CaCESA: Cassava diseases in central, eastern and southern Africa). These diseases cause losses estimated at $1,200 annually (Thresh *et al.*, 1997).

The two major viral diseases, spread by a whitefly vector (*Bemisia tabaci*) and the movement of planting materials, now pose a severe threat to cassava culture in many regions. According to researchers at the National Agricultural Research Organisation, cassava brown streak disease is a devastating disease that causes loss of cassava root (tuber) production and quality. It can render susceptible varieties unusable if cassava roots are left in the ground for over nine months.

Given the severity of the current cassava disease outbreaks and the threat they pose to the food security of millions of people in Africa, several international organisations and partnerships are working to restore cassava production systems, particularly among the Great Lakes countries of East Africa. FAO, with the European Union support, is active in the multiplication and distribution of clean (disease-free) re-planting materials.

Natural hazards are potentially damaging physical events, phenomena or human activities that may cause injury or loss of life, damage to property, social and economic disruption or environmental degradation. They result from natural processes of the earth, including floods, landslides, droughts, volcanic eruptions, earthquakes, tsunamis, cyclones and other geological processes (ICSU, 2005). Disasters are a function of vulnerability to the impacts of these processes and occur from a combination of hazards, conditions of vulnerability and insufficient measures to reduce negative consequences. They are serious disruptions of the functioning of communities and cause widespread human, material, economic or environmental losses.

The economic damage of natural disasters in Africa between 1974 and 2003 is estimated at $35,144 million with majority of the effects occurring in eastern and northern Africa (Guha-Spair *et al*., 2016; Table 4.2; Box 4.2). Some of the most devastating disasters recent decades include droughts in the Sahel (1972–1973), Ethiopia (1983–1985), East (2011) and southern (2014–-2015) Africa; floods in Central (2002), North (2009 and 2010) and Southern (2010–2011) Africa; and the volcanic eruption of Nabro (2011). The frequency of disasters is increasing on the continent with data demonstrating that the East African region is under the greatest threat from natural disasters (Lukamba, 2010). This region has experienced the highest recorded number of disaster events over the past 30 years, followed by the West African region. Northern Africa is placed third followed by the Southern Africa (Table 4.2), whereas the least disaster-prone region is central Africa (Lukamba, 2010). Eastern Africa recorded more than 67% of victims killed or affected between 1974 and 2003, and Northern Africa experienced 53% of the economic damages for the same period. The most frequent disaster recorded during the 30 years (from 1974 to 2003) was hydrometeorological, followed by floods (Table 4.2).

Box 4.2: A treatise of natural disasters in Africa

In 2015, Africa suffered from 62 natural disasters compared to 2005–2014 annual average which was 68 (Guha-Spair *et al.*, 2016). This affected 30.9 million people. Approximately 28 million were affected by climatological disasters. Hydrological disasters accounted for impacts on 2.8 million people who were largely victims from flooding in Somalia (900,000 people), Malawi (639,000 people) and Madagascar (174,000 people). The economic estimate of the disasters were made for only 11 events, highest being drought in South Africa ($1billion), floods in Malawi ($400 million) and a storm in Egypt ($100 million).

Long-term effects of natural disasters on wildlife are usually assumed to be small. These may, however, amplify through interactions with other drivers leading to enhanced invasions by promoting the transport of propagules into new regions, decreasing the resistance of native communities to establishment of invasive non-native species, or by putting existing non-native species at a competitive advantage (Diez *et al.*, 2012). For instance, volcanic lava flows have been shown to facilitate tree invasion in the Reunion Island by enhancing the spread of Casuarina (*Casuarina equisetifolia*) by 20-fold (110–2,373 hectares) over a 40 year (1972–2012) period (Potgieter *et al.*, 2014). It is widely acknowledged that those who are most vulnerable to natural disasters and climate change are those who typically live in poor quality housing in low-income informal settlements that lack provision for basic infrastructure and services (Adelekan *et al.*, 2015).

Table 4.2: Number of natural disasters in different subregions of Africa from1974 to 2003. (Notes: Ndr = Number of disasters reported; na = no data available)

Category	Type of natural disaster	Subregion	**1974 – 1978**	**1979 – 1983**	**1984–1988**	**1989-1993**	**1994 – 1998**	**1999 – 2003**	**1974 – 2003**
Geophysical	Volcanic	Eastern	3	ndr	ndr	1	ndr	ndr	4
		Middle	1	ndr	2	ndr	ndr	3	6

		Northern	ndr	ndr	ndr	ndr	ndr	ndr	ndr
		Southern	ndr	ndr	ndr	ndr	ndr	ndr	ndr
		Western	ndr	ndr	ndr	ndr	1	ndr	1
		Total	**4**	**ndr**	**2**	**1**	**1**	**3**	**11**
	Earthquakes and tsunami	Eastern	ndr	ndr	1	3	1	4	9
		Middle	ndr	ndr	ndr	1	ndr	ndr	1
		Northern	ndr	2	3	5	2	4	16
		Southern	ndr	1	2	ndr	ndr	ndr	3
		Western	ndr	1	0	ndr	ndr	ndr	1
		Total	**ndr**	**4**	**6**	**9**	**3**	**8**	**30**
Climatological	Drought	Eastern	8	18	19	18	16	49	128
		Middle	6	8	7	4	2	4	31
		Northern	1	7	4	3	5	8	28
		Southern	ndr	8	8	12	7	10	45
		Western	27	30	22	7	5	10	101
		Total	**42**	**71**	**60**	**44**	**35**	**81**	**333**
Hydrological	Flood	Eastern	16	9	11	19	34	73	162
		Middle	ndr	ndr	4	5	10	28	47
		Northern	6	10	5	7	16	30	74
		Southern	3	1	5	2	7	13	31
		Western	3	4	14	7	24	46	98
		Total	**28**	**24**	**39**	**40**	**91**	**190**	**412**
Meteorological	Windstorm	Eastern	10	10	12	8	12	24	76
		Middle	1	1	1	ndr	ndr	3	6
		Northern	ndr	1	2	ndr	2	4	9
		Southern	1	1	3	3	4	10	22
		Western	2	1	3	2	1	10	19
		Total	**14**	**14**	**21**	**13**	**19**	**51**	**132**
Natural disasters with economic damages		Eastern	13	9	8	7	13	8	58
		Middle	2	1	2	0	1	2	8
		Northern	2	3	2	4	6	9	26
		Southern	1	1	5	1	2	6	16
		Western	21	5	6	1	3	7	43
		Total	**39**	**19**	**23**	**13**	**25**	**32**	**151**

4.2.2. Anthropogenic direct drivers

Anthropogenic direct drivers comprise human induced drivers whose impact can be directly observed and monitored.

4.2.2.1. Land-use and land-cover change

Land conversion from natural vegetation to farmlands, grazing lands, infrastructure, human settlements and urban centres contributes significantly towards loss of biodiversity and ecosystem functionality (Biggs *et al.*, 2008; Maitima *et al.*, 2009). In Africa, a large proportion of livelihoods depend on natural resources including minerals, agriculture, fisheries, and forestry. Agricultural expansion and mining are the dominant drivers of biodiversity loss (Biggs *et al.*, 2008), particularly due to conversion of natural habitat to cultivation land or as a result of open cast mining activities. There has been an expansion of cash crops, much of this as large-scale cropland cultivation that has been termed the Green Revolution. Land-use change is worsened by the growing land grab phenomenon where foreign investors are allocated large pieces of land for agriculture, especially crop production (Cotula *et al.*, 2009; Byerlee *et al*., 2013), with great impact on indigenous and local populations, natural resources, local knowledge and quality of life in general (Cotula *et al.*, 2016).

Habitat fragmentation compounds the impacts of habitat loss, preventing migration and creating island biogeography effects where small fragmented habitats hold less biodiversity than larger habitats. Evidence shows that tropical forest fragments suffer twice the total number of extinctions than unfragmented forests (Brooks *et al.*, 1999). Habitat conversion may also result in loss of ecologically critical areas such as suitable breeding grounds (e.g., wetlands for birds) or seasonal grazing areas, where impacts on biodiversity may be far higher than the proportion of land lost. Small-scale farming is increasingly being driven by population growth in most areas of Africa. As population density increases, there is a move from shifting agriculture to intensification of permanent agricultural fields. The total area cultivated is strongly associated with loss in indigenous plant abundance (Biggs *et al.*, 2008) and indirectly results in loss of mammal and bird species. In Uganda and Tanzania, mammal species richness has been reported highest in grazing lands and lowest in cultivated areas (Msuha *et al.*, 2012; Kiffner *et al.*, 2014), partly due to complete destruction of habitat in cultivated lands. This suggests that continued expansion of lands under cultivation will lead to shrinking of wildlife habitat and further threaten mammalian communities. Loss of space for wildlife due to increased areas of cultivation and grazing lead to human-wildlife conflicts. There is need for policy intervention to ensure balance between livelihoods of farmers and pastoralists and wildlife in these mixed-use landscapes.

Another effect of fragmentation of landscapes is the disruption of migration and movement of wildlife species (Kiffner *et al.*, 2014). In addition, conservation areas have been reported to augment fragmentation and do not provide sufficient wildlife habitat. For example, the development of veterinary cordon fences in Botswana and Namibia to control diseases and comply with international sanitary and phytosanitary standards for meat exports has led to decline in wildebeest and other wildlife due to fragmentation of their habitat. Hence, there is a need to have corridors to ensure functional connectivity between wildlife populations and other organisms across fragmented landscapes. Africa has tended to engage in agricultural expansion as opposed to the global norm of agricultural intensification (Reardon *et al.*, 2001). Whereas the area of land under agriculture has actually decreased globally due to improved yields, in Africa there is still rapid agricultural expansion (Reardon *et al.*, 2001). This is mostly linked to small-scale agriculture production on near subsistence type farms. Low soil fertility, and low use of artificial fertilizers means that disproportionally large areas of agriculture are needed to produce relatively small (in global terms) quantities of agricultural production (Wood *et al.*, 2004; Brink *et al.*, 2009; von Maltitz *et al.*, 2012).

Unsustainable harvesting is leading to extensive loss of African forests, with high deforestation rates being reported for many African countries. Households derive income from the informal production of woodfuel ($3,705 million at 2011 prices), charcoal ($10,585 million at 2011 prices) and forest products used for house construction ($112 million at 2011 prices) (FAO, 2015). Indications are that the rate of deforestation is slowing in most countries (de Wasseige *et al.*, 2013; FAO, 2015), but Africa is still globally one of the areas with the highest rates of forest loss. The consequence on biodiversity particularly loss of vulnerable species with narrow ecological niche is a major concern, as natural habitats are completely lost.

Box 4.3: Impact of mining on protected areas in Africa

Africa is rich in natural resources with large underground desposits of cobalt, diamond, gold, iron, phosphates, etc. Access to mineral reserves is through opencast or underground mining with impacts on natural areas and biodiversity (Duran *et al.*, 2013). A proportion of 44% of Africa's major metal mines are inside or within 10 km of a protected area (see table below) (Edward *et al.*, 2013). Mineral exploration and exploitation is linked with major infrastructural development, such as roads, railway, ports and hydropower dams. These have direct and indirect impacts on biodiversity including removal, fragmentation and degradation of natural habitats (Duran *et al.*, 2013). Of greatest concern is the downgrading, downsizing, and degazettement of protected areas as exemplified by the loss of 1,550 hectares of Mount Nimba Biosphere Reserve, a World Heritage site in the Republic of Guniea (Edward *et al.*, 2013).

Examples of Protected Area downgrading, downsizing, and degazettement (PADDD) for mining prospecting or extraction in some African countries. Downgrading relates to a reduction in the level of legal protection, downsizing to a reduction in park area, and degazettement to a removal of formal protection. Source: Edward *et al.* (2013).

Country	Location	PADDD	Year	Area km^2	Mining activity
Guinea	Mount Nimba World Heritage site	Downsize	1993	15.5	Iron-ore prospect
Zambia	19 National Parks	Downgrade	1998	63,585	Mining
Uganda	Queen Elizabeth National Park	Downgrade	2005	Unknown	Limestone
DRC	Basse Kando Reserve	Degazette	2006	Unknown	Mining
South Africa	Marakele National Park	Downgrade	2009	Unknown	Unknown
Tanzania	Selous Game Reserve	Downsize	2012	200	Uranium

Infrastructure development, including urban sprawl and mining, is resulting in habitat loss and land conversion (Box 4.3). Most African cities are expanding at a rapid rate, way in excess of national population expansion rates (Young *et al.*, 2009; Freire *et al.*, 2014). This is driven by increased rural-urban migration. In addition to habitat loss from this urban expansion, there is a secondary impact driven by the need to fuel and feed this growing urban population. For instance, both Dar es Salaam and Maputo have a far-reaching footprint in terms of deforestation (to provide the urban charcoal needs) that extends over 300 km along main arterial routes out of the city (Tadross *et a*l., 2012).

4.2.2.2. Deforestation

Deforestation is a global problem. Statistical data showing the long-term trends for Africa (Box 4.4). Deforestation in Africa has mostly been caused by demand for wood and non-wood products for commercial purposes associated with trade and development, or subsistence of communities around forests. Generally, there has been a tendency towards lose than gain of forest areas in Africa, with most losses occurring in areas with medium to high tree densities (Figure 4.7). Africa lost the highest percentage of tropical forests compared to other continents during the 1980s, 1990s, and early 2000s. The actual loss was 3.4 million hectares annually between 2005 and 2010 (FAO, 2010). Some of the main causes have been classified as illegal industrial and artisanal logging, unsustainable mining, commercial agriculture, infrastructure development, expansion of oil palm cultivation and urban demand for wood fuel or charcoal. Deforestation and fires are also linked with agricultural activities such as slash-and-burn. During severe droughts as in El Niño years, African rainforests may become more susceptible to fire. The most destructive fires occur in forests that have burned previously (Cochrane *et al.*, 1999). Deforestation impacts negatively on local and indigenous peoples via loss of natural resources and therefore loss of habitats they rely on for food, medicine, traditional rituals and social stability and the loss of the traditional and cultural knowledge related to the management of these resources and ecosystems (Kipalu *et al.*, 2016).

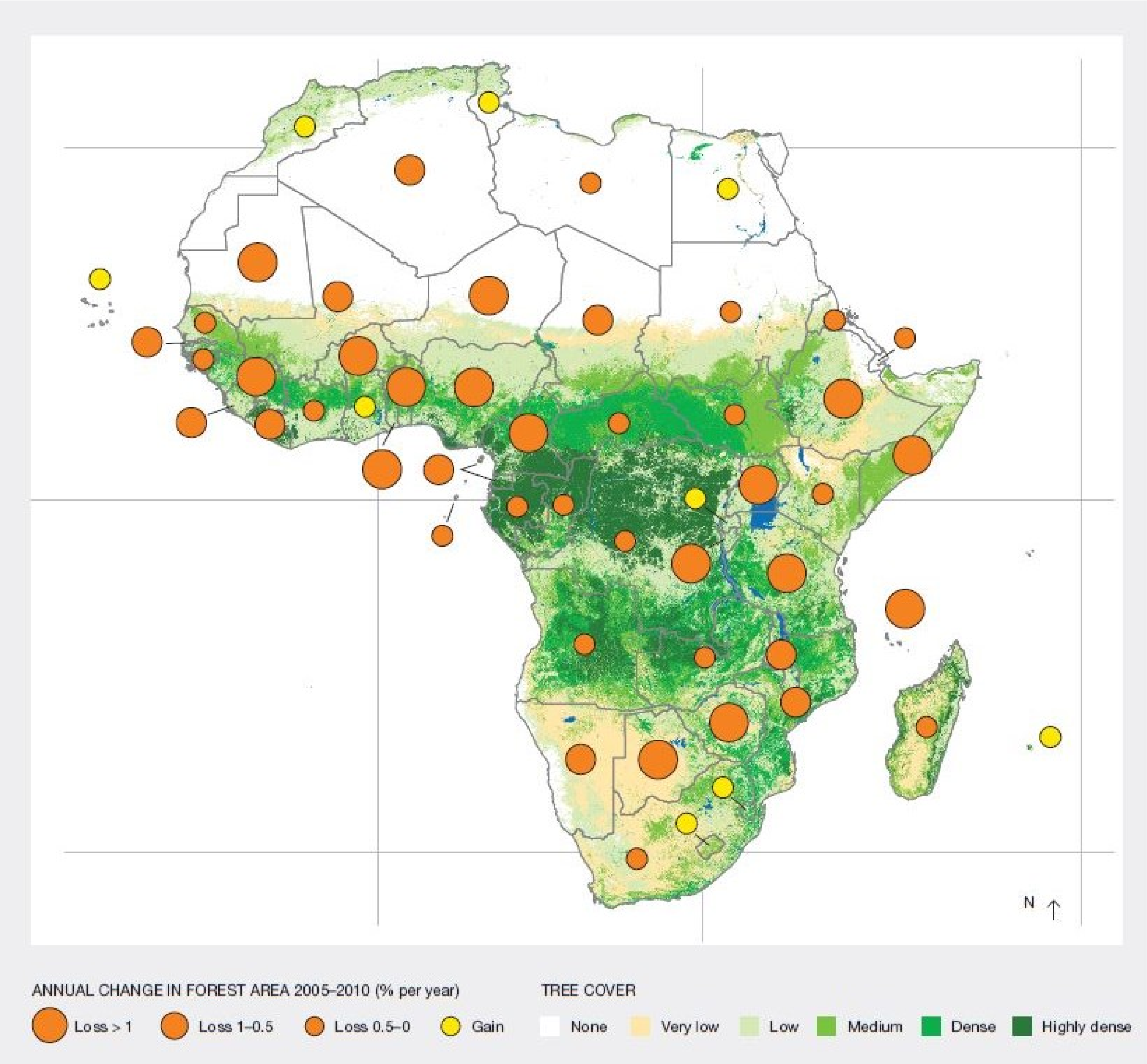


Figure 4.7: Annual damage in Forest area 2005–2010 in Africa. Source: Pesche *et al.* (2016).

Box 4 4 Africa forest resources assessment statistics.

Data collection and reporting leading up to 2015 was guided by a series of workshops and training sessions designed to maximize consistency between reports (FAO, 2016). For Forest Resources Assessment 2015, data were also acquired through the Forest Resources Information Management System, the online data collection portal of FAO. Countries were given templates with data they had submitted for forest resources assessment 2010. Countries were requested to revise and update the former figures when new data were available and then estimate the figures for 2015. In addition to providing the data reported by countries, FAO has worked with national correspondents to provide data assembled from other sources. Most of these are sources previously provided by national governments to the United Nations, including data on population, land area and wood removals (FAO, 2016). Table provided in this Box provides summary statistics for African forest resources assessment.

Variable (unit, year)[a]	TOTAL	DIRECTION OF CHANGE[B]	ANNUAL CHANGE[B] (%)	DATA AVAILABILITY[C] (STATUS/TREND)
Forest area (million hectares, 2015)	624	↓	-0.49	H/H
Natural forest (million hectares, 2015)	600	↓	-0.54	H/H
Planted forest (million hectares, 2015)	16	↑	1.34	H/H
Net annual forest change (million hectares, 2010–2015)	-2.8			H/*
Net annual forest change (million hectares, 2010–2015)[d]	-3.1			H/*
Net annual planted forest change (million hectares, 2010–2015)	0.2			H/*
Forest growing stock (billion m^3, 2015)[e]	79	↓	-0.37	H/H
Forest growing stock (m^3 per hectare, 2015)[e]	128	↑	0.13	H/H
Carbon in above-and below-ground biomass (giga tons, 2015)[e]	60	↓	-0.43	H/H
Carbon in above-and below-ground biomass (tons per hectare, 2015)[e]	96	↑	0.07	H/H
Production (million hectares, 2015)	165	↓	-0.77	H/M
Multiple-use forest (million hectares, 2015)	133	↓	-0.46	H/M
Total wood removals (million m^3, 2011)	614	↑	2.12	H/H
Protection of soil and water (million hectares, 2015)	50	↓	-0.15	M/L
Ecosystem services, cultural or spiritual values (million hectares, 2015)	67	↓	-0.30	L/L
Conservation of biodiversity (million hectares, 2015)	92	↑	0.75	H/M
Primary forest (million hectares, 2015)	135	↓	-0.45	H/H
Forest area within protected areas (million hectares, 2015)	101	↑	0.66	H/M
Forest area burned (million hectares, 2010)	19			H/*
Forest area with reduction in canopy cover (million hectares, 2000–2010)	50			H/*

4.2.2.2.1. Central Africa (Congo Basin)

In a global context, annual deforestation rates are relatively low in Central Africa, compared to other rainforests in Southeast Asia and South America. Population density, small-scale agriculture, fuelwood collection and forest's accessibility are closely linked to deforestation, whereas timber extraction has no major impact on the reduction in the canopy cover (Ernst *et al.*, 2013; Gillet *et al.*, 2016). Given the extent and rate of forest fragmentation from roadside farming and logging, basic simulations suggest that up to 30% of forests will disappear by 2030. The forests of Congo Basin are being harvested at unprecedented rate, in particular, due to rapidly rising demand from China (WWF, 2017). A doubling of gross deforestation rates from 0.11%/year between 1990 and 2000 to 0.22% between 2000 and 2005 was demonstrated (Ernst *et al.*, 2013). However, deforestation in Congo Basin has since considerably decreased (Megevand *et al.*, 2013).

4.2.2.2.2. West Africa

Deforestation has already wiped out a large extent of natural forests of West Africa's with only 22.8% moist forests remaining, many in a degraded state (FAO, 1997). Deforestation and degradation of West Africa's tropical forest areas (e.g., in Nigeria) is occurring due to the expansion of smallholder cocoa farms that depend on environmentally destructive practices like slash-and-burn clearing methods. Most deforestation occurred before 1975, with a loss of 84% of the original forest extent. Between 1975 and 2013, forest removal in the Upper Guinean countries for wood products, plantations, farming and other uses was still ongoing, and resulted in the loss of 28% (65,000 km^2) of the forest (Figure 4.8). Deforestation has been associated with the severe outbreak of Ebola in West Africa (Bausch *et al.*, 2014). "The destruction of natural habitat of fruit-eating bats drove them closer to human settlements for food and thus exposing human populations to the transmission of the Ebola virus from bats" (The Guardian, 2015).

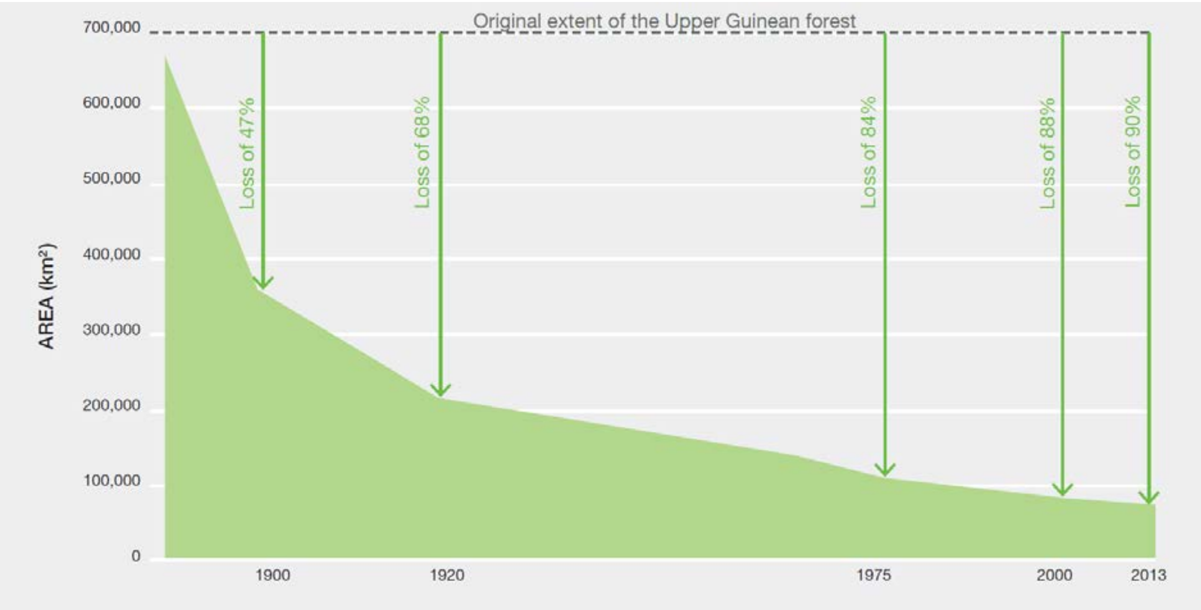


Figure 4.8: Evolution of dense forest extent in the Upper Guinean countries. Source: USAID (2014).

4.2.2.2.3. Southern Africa

In Southern Africa, deforestation and forest degradation is considered a major problem contributing to greenhouse gases emissions and having negative impacts on biodiversity and the balance of the associated ecosystems (Lesolle, 2012). The annual forest loss in the Southern African Development Community regions was 0.46% (1.8 million hectares) between 2005 and 2010 (FAO, 2010; Figure 4.9). Efforts to curb forest fires in southern Africa have involved programs such as the Burning for Biodiversity in Southern Africa project that brings together biodiversity research with capacity building and external communication to promote effective fire and conservation management in South African savannas. Findings from this program highlight that, surprisingly, burning generally had little effect on many faunal groups. This is critical information for more effective fire management for biodiversity conservation and enables a more flexible approach to burning in many conservation areas (FAO, 2010).

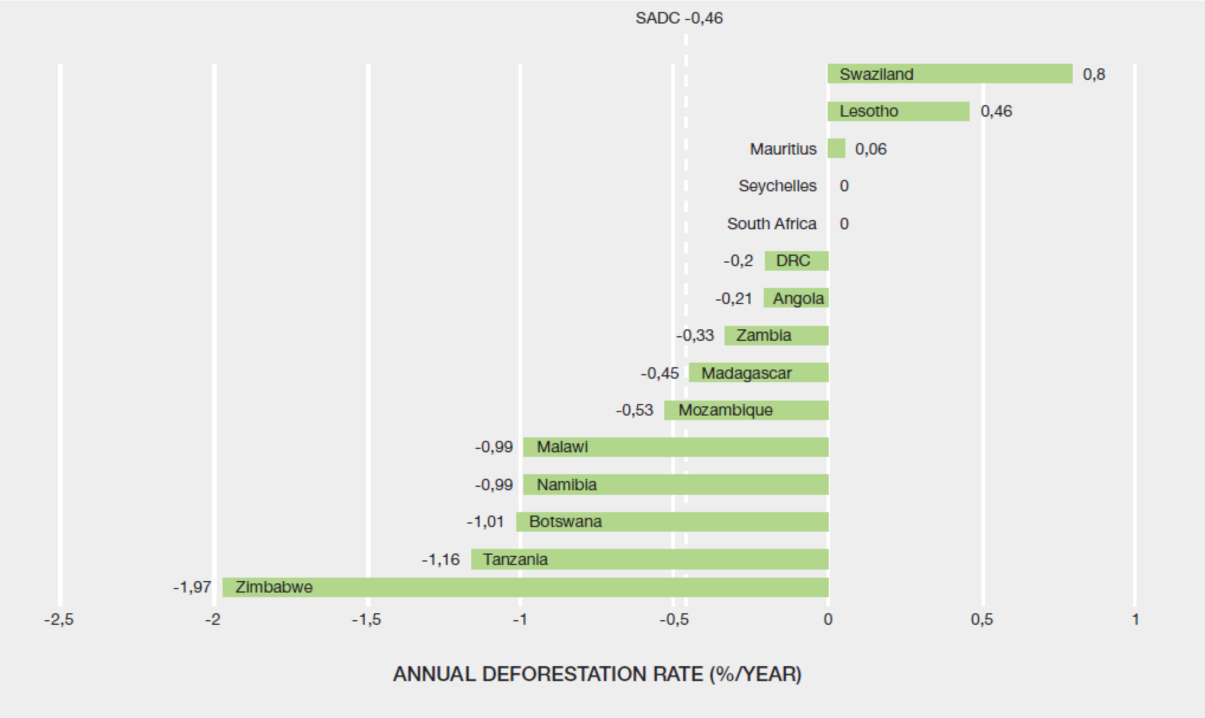


Figure 4.9: Annual deforestation rate in the Southern African Development Community regions, 2005–2010. Source: FAO (2010).

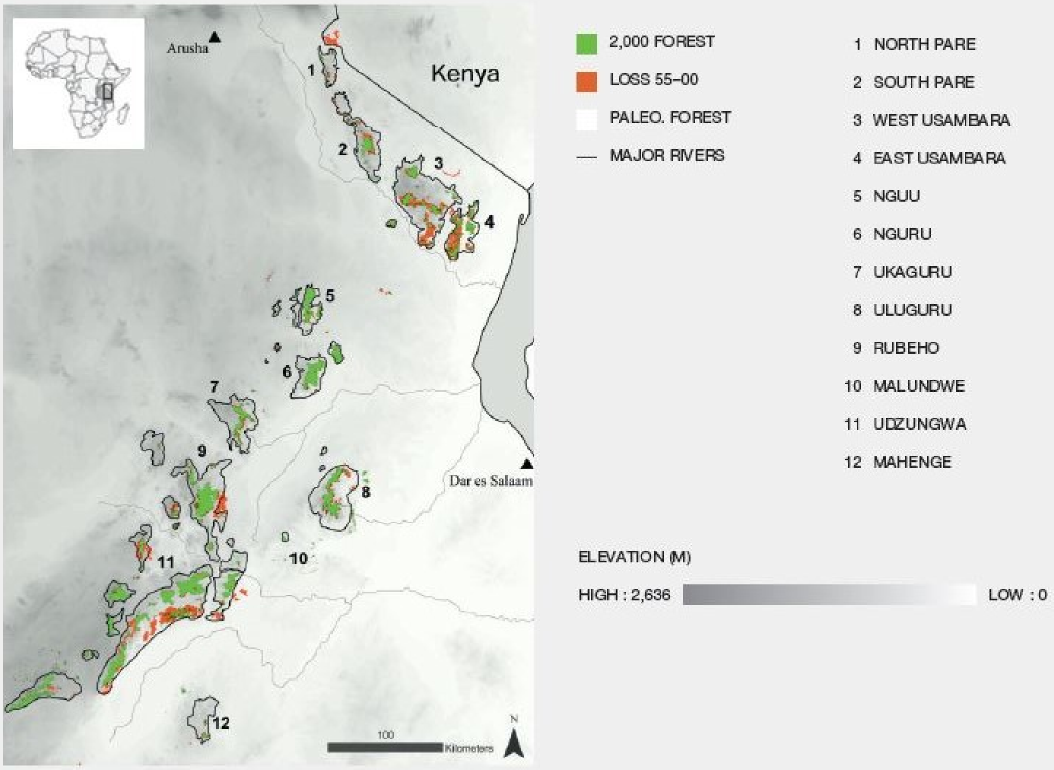
4.2.2.2.4. East Africa and adjacent islands

East African coastal forests are a narrow belt with abundant fauna and flora, most severely threatened by deforestation. For this reason, they are considered priority conservation areas globally. The region has 1,366 and 100 endemic plants and animal species, respectively (WWF-US, 2003). Since the arrival of humans 2,000 years ago, Madagascar has lost more than 90% of its original forests. Most of this loss has occurred since independence from France, as a result of local people using slash-and-burn agricultural practices as they try to subsist (WWF, 2001). The coastal forests of Tanzania and Kenya have been reduced to less than 10% of their original area (Sloan *et al.*, 2014). The main causes may be similar (as above) in different countries but the extent forests covers and drivers for deforestation vary among the countries (Naidoo *et al.*, 2013). For example, the Kaya forests in coastal Kenya, for long time has been a hotspot for biodiversity and ecosystem services but in recent decades has been lost due to the interplay of direct and indirect drivers (Githitho, 2005). Additional case studies from East Africa are presented in Box 4.5).

The loss of forest areas in most countries in East Africa and adjacent islands have been associated with increased human settlement and agriculture, inappropriate energy technologies, unplanned urbanisation, unregulated use of forest resources and insufficient local and national intervention (Chapman *et al.*, 2000; Matiku, 2005). Tobacco production was to a great extent responsible for deforestation in East Africa since the early 1900s. The impacts are not only from clearing for farms, but also from the curing process. Approximately 3 hectares of trees are cleared to provide fuel to cure one hectare of tobacco (Lee *et al.*, 2016). The environmental impacts of tobacco farming in large-scale farms also include massive use of water and air and water pollution (Lee *et al.*, 2016).

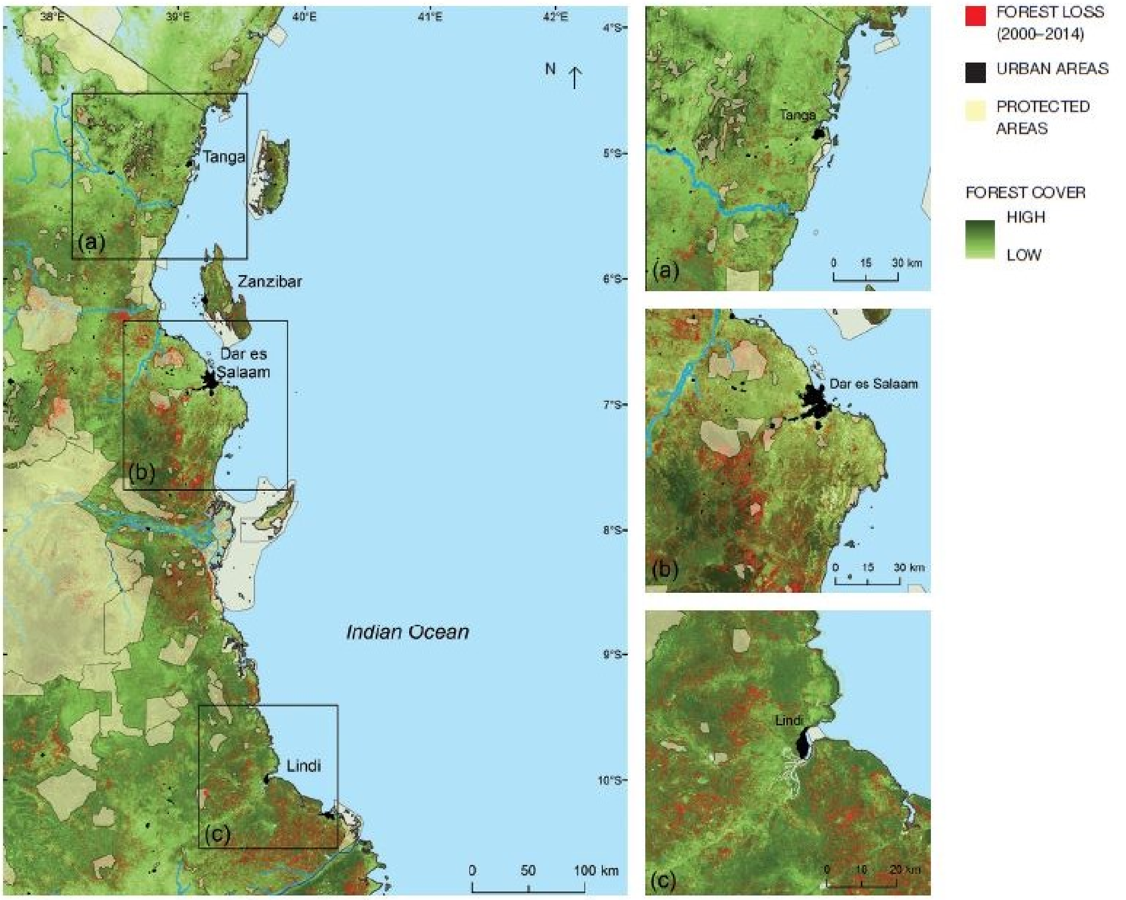
Box 4 5 Forest Analyses in East Africa.

The Eastern Arc Mountains of Tanzania have exceptional global importance for the conservation of endemic plants and animals. Studies show that deforestation has preferentially occurred in the lower and middle elevations of the mountains and that this has happened more in some mountain blocks than others (e.g., Burgess *et al.*, 2017). By linking deforestation trends to the distribution of endemic trees, it was possible to better address concerns in the then Red Listing of threatened trees. The elevational distribution of Eastern Arc closed forest and the processes of deforestation affecting the ecosystem are important factors to consider when developing a comprehensive conservation plan for an ecosystem in which species of concern are restricted to defined elevation ranges (see figure below).



The Eastern Arc Mountains of Tanzania, illustrating area of forest in year 2000, forest lost since 1955 and the paleoecological estimation of forest extent, with elevation as a background. Source: Hall *et al.* (2009).

Another analysis of changes of state, pressures and conservation responses over 20 years in East Africa, represented by the Tanzanian portion of the Coastal Forests biodiversity hotspot is reported by Burgess *et al.* (2017). Baseline data collected during 1989–1995 was compared with data from a synthesis of published papers and reports, and field work carried out across the region during 2010–2014. It was found that biodiversity endemism values were largely unchanged, although two new species (amphibian and mammal) had been named and two extremely rare tree species had been relocated. However, forest habitat continues to be lost and degraded, largely as a result of agricultural expansion, charcoal production to supply cities with cooking fuel, logging for timber and cutting of wood for firewood and building poles. Habitat loss is linked to an increase in the number of species threatened over time. Human-use pressures remain intense in many areas, and combined with emerging pressures from mining, gas and oil exploration, many endemic species remain threatened with extinction (Burgess *et al.*, 2017; see figure below).



Forest cover and forest loss in coastal Tanzania during 2000–2012. (A) Based on raw data from Hansen *et al.* (2013): (a) Forest change around the East Usambara–Tanga town area in northern Tanzania; (b) forest loss around the capital city, Dar es Salaam; (c) forest change in southern Tanzania, towards the Mozambique border. (B) Based on further analysis and processing to show forest, woodland and mangrove cover and loss and the major urban centres in the same coastal region of Tanzania (analysis from Tabor *et al.*, 2013).

4.2.2.3. Climate change

It is generally agreed that anthropogenic activities including the burning of fossil fuels and unsustainable land-use changes (deforestation and forest degradation) around the world have resulted in a significant increase in the concentrations of heat-trapping greenhouse gases which include CO_2, CFCs, CH_4, and N_2O (Myhre *et al.*, 2013). As a continent, Africa has contributed a trivial proportion of global emissions, only 2.5% of fossil fuel emissions in the 1980 to 2005 period, despite having 13.8% of the global population (Le Quéré *et al.*, 2009). Within Africa, greenhouse gases emissions is uneven, for instance, almost 38% of the total was from South Africa alone, rising to 60% if Egypt and Nigeria are included (Canadell *et al.*, 2009). Per capita Africa emissions are among the lowest in the world at 0.32 tons of Carbon/year versus a global average of 1.2 tons of Carbon/ear. What is strikingly unique about Africa's emissions is that just less than half is from land-use change and deforestation (Le Quéré *et al.*, 2009a). High population growth, if current development pathways are left to continue with limited climate-smart technologies adopted, may significantly increase Africa's contribution to greenhouse gases emissions over the next century (Gornall *et al.*, 2010).

Despite Africa's low contribution to greenhouse gases emissions, Africa will be one of the region's most severely impacted by climate change, with the IPCC Fifth Assessment Report emphasizing negative impacts on water availability and food production (Myhre *et al*., 2013). This constrains Africa's ability to develop, unless mitigation measures are undertaken (Wright *et al.*, 2015; Connolly-Boutin *et al.*, 2016). In addition to elevating human pressure on natural resources due to a decline in agricultural productivity, anthropogenic climate change is also anticipated to be a major driver of biodiversity loss; changes in ecosystem structure and function; and the ability of ecosystems to supply nature's contributions to people (Perrings, 2010; Bellard *et al.*, 2012; Scholes, 2016). The degree to which this will impact on biodiversity and the provisioning of nature's contributions to people remains uncertain as it depends on both the global ability to mitigate emissions as well as uncertainty around how the future climate which is already affected by global warming will impact both biodiversity and nature's contributions to people provision (Scholes, 2016). Changes in the seasonality of rainfall as well as within and between season variability could have profound effects on vegetation structure and net primary production (Rohr *et al.*, 2013; Cramer *et al.*, 2015). For instance, biodiversity of the Mediterranean vegetation at the southern tip of Africa (fynbos) is totally dependent on winter rainfall, whilst the savannas are dependent on the existence of a long dry winter period (Mucina *et al.*, 2006). For coastal systems, a rise in temperature, increased storm surge and sea level rise all pose threats, with estuarine systems being particularly vulnerable (Magadza, 2000). Loss of mangrove vegetation from these estuarine systems will exacerbate the storm surge hazards leading to disasters (McIvor *et al.*, 2012).

Globally, climate change is anticipated to have major impacts on species extinctions (Thomas *et al.*, 2004; Jetz *et al.*, 2007; Foden *et al.*, 2013), though the true magnitude of impact is hotly debated and uncertain. The IPCC (2007) estimate, based on a variety of scenarios, that climate change could result in the losses of about 5,000 African plant species, over 50% of some bird and mammal species, and decline the productivity of Africa's lakes by between 20 and 30% by 2100 (IPCC, 2007). About one-fifth of all known species of plants, mammals and birds, and about one-sixth of amphibians and reptiles are found in Africa (Midgley *et al.*, 2007); the regions four biodiversity hotspots together today host 3.5% of the worlds' endemic plant species and 1.8% of endemic vertebrate species in areas that have been reduced by 73.2% and 93.3% relative to their original areal extents (Myers *et al*., 2000), indicating that even without climate change, there is a high level of threat to Africa's endemic biodiversity (Midgley *et al*., 2007). Disturbance by fire and grazing are also key components of future global change impacts (Bond *et al.*, 2003). A scenario analysis using land-use, climate change, nitrogen deposition, biotic exchange (alien organisms) and rising atmospheric CO_2 as the five main drivers of future global biodiversity in that order of importance and assuming no interactions between drivers, concluded that human land-use impacts were most critical in savannas and tropical forests, with climate change impacts second-most important, or most important in other ecosystem types in Africa (Sala *et al.*, 2000).

Impacts on both freshwater and coastal systems may also be severe, with sea level rises, changes in upwelling, sea surges, sea temperature changes and pH changes also likely to impact on coastal ecosystems. Increases CO_2 in the oceans will increase water acidity and this, coupled with increased temperature will have profound impacts including coral bleaching (Hoegh-Guldberg *et al*., 2007) and the de-calcification of shells of molluscs (Parker *et al.*, 2013). At high CO_2 concentrations this may lead to total collapse of coral systems and the multitude of ecosystem functions they support, including being an important component of many fisheries. Most of the large biodiversity-rich lakes on the continent are sensitive to climate change as their water balances are dominated by rainfall on the lakes and evaporation (Spigel *et al.*, 1996). The smaller lakes receive significant water inputs from inflowing rivers as opposed to rainfall, but are equally strongly affected by evaporation and their water balances of the lakes are also affected by abstraction for use in agriculture and industry. The lake waters, for example in Lake Malawi and Tanganyika, are now getting warmer in tandem with the rise in global temperatures, and this has affected fisheries production due to increased thermal stratification which results in less mixing and nutrient exchange between surface and deep waters thus affecting primary production and thus a cascading effect on the aquatic food-webs. The resulting reduction of food availability will affect fisheries and thus livelihoods (Hecky *et al.*, 1994; Bugenyi *et al.*, 1996).

Not only will climate change result in extinctions, but it is also likely to change the structure and function of the biota in many areas (Hole *et al.*, 2009).). Individual species or entire ecosystems will need to, in effect, migrate across the landscape to track suitable climates. The ability of species to migrate will differ per taxa, will be dependent on the existence of migratory corridors, and will be hindered by anthropogenic land-cover change and habitat fragmentation (Hannah *et al.*, 2002; von Maltitz *et al.*, 2007; Baker *et al.*, 2015; Belle *et al.*, 2016). It is probable that future ecosystem will have different structure, function and species mixes compared to the present (Hannah *et al.*, 2002). One consequence is that current reserve networks may need to be re-aligned to account for the climate change. A set of studies in West Africa have found that the current reserves configuration under future climates scenarios will lead to a decreased suitability across the protected area network of 55% for birds, 63% for amphibians, and 63% for mammals (Baker *et al.*, 2015). A similar need for a realignment of conservation areas in response to climate change in South Africa has been shown (Hannah *et al.*, 2007).

The direct impact of globally increased concentration of CO_2 is likely to have profound impacts on the species distribution within the terrestrial environment, and may conceivably be a direct contributor to biome level change (Steffen *et al.*, 2007; West *et al.*, 2012). A recent study (Midgley *et al.*, 2015) shows that the vast African savannas, with its icon fauna and flora, may be partly lost as a direct impact of CO_2 enrichment effects. If emissions continue on a 'business-as-usual' path, by mid-century, CO_2 levels will exceed those last seen more than 25 million years ago–far predating the rise of grasslands and savanna's C4 grasses, which dominate through the continent (West *et al.*, 2012). Having evolved under high CO_2 concentration (Franks *et al.*, 2013), an increase in CO_2 will facilitate C3 plant species ability to rapidly accumulate woody biomass through faster growth, and this will enable them to escape the "fire trap" created from frequent grass fires (Bond *et al.*, 2012; West *et al.*, 2012). There is increasing evidence that a raised CO_2 concentration may favour woody perennials over C4 grasses (Bond *et al.*, 2000; 2012). The large-scale woody plant densification (referred to in Southern Africa as bush encroachment) is regarded as a complex response to multiple drivers including increased grazing pressure with reduced fire (O'Connor *et al.*, 2014). However, the impacts of raised CO_2 may be an additional important driver in this process and may lead to bush encroachment even in well-managed areas. Bush encroachment regardless of its cause, has had profound impacts on the provisioning of ecosystems services, and especially cattle grazing, across vast areas of the savanna, (Donaldson, 1980; De Klerk, 2004; O'Connor *et al.*, 2014) with an estimated 260,000 km^2 being affected in just Namibia. Of particular concern regarding climate change is "tipping points" where ecosystem thresholds can lead to irreversible shifts in biomes (Leadley *et al.*, 2010). Raised CO_2 may cause a tip between savanna and forest systems (Higgins *et al.*, 2012; West *et al.*, 2012).

A number of dynamic vegetation models have attempted to model changes in vegetation functional types in response to climate change (Scheiter *et al.*, 2013; Che *et al.*, 2014). These indicate that extensive shifts in biomes are likely. The role that fire plays in the distribution of future biomes is critical as has been demonstrated by running the same models with fire sub-sections disabled. In Southern Africa the grasslands are likely to retract extensively and be replaced by savanna or forest.

Savannas may change to forest in other areas of Africa (Higgins *et al.*, 2012). These dynamic vegetation models suggest savanna vegetation is far less stable than earlier outcomes from simpler niche-based models, where CO_2 and fire effects are not considered, indicated (Midgley *et al.*, 2015). Carbon dioxide fertilization effects may make some plants more drought hardy, and this will slightly compensate for temperature rise. It also means that globally there should be, on balance, an overall greening (Zhu *et al.*, 2016). However, raised CO_2 may also lead to an increased synthesis of secondary compounds in the plant, potentially changing the ratio of carbon to nitrogen and hence reducing palatability (Schadler *et al.*, 2007; Craine *et al.*, 2017). Although data on this is still poorly researched, especially for Africa, impacts could be profound, and may reduce the flow of nature's contributions to people resulting from animal production (Owensby *et al.*, 1996; Milchunas *et al.*, 2005; AbdElgawad *et al.*, 2014; Craine *et al.*, 2017).

Climate change will influence environmental conditions that can enable or disable the survival, reproduction, abundance, and distribution of pathogens, vectors, and hosts, as well as the means of disease transmission and the outbreak frequency hence a major driver to emerging diseases (Wu *et al.*, 2016). These could cause shifts in the geographic and seasonal patterns of human infectious diseases, hence changes in outbreak frequency and severity (Wu *et al.*, 2016). In Africa, the neglected tropical diseases, such as soil-transmitted helminths, are the most common conditions affecting the poorest 500 million people living in sub-Saharan Africa.

Many communicable diseases are water borne and climate change is therefore likely to impact incidences and prevalence of these diseases by increasing the range and seasonal duration of causative pathogens (UNECA, 2011). Climate change induced increased frequency of extreme weather events is likely to exacerbate water-borne diseases (e.g., diarrhoea) and may have major influence on vector-borne disease epidemiology (reviewed in UNECA, 2011). For instance, the Rift Valley Fever, which has a widespread occurrence in the continent, has pronounced periods of virus activity in East Africa during periods of heavy, widespread and persistent rainfall associated with El Niño events (Linthicum *et al.*, 1999; Martin *et al.*, 2008).

Climate change is expected to have direct, and in most cases negative impacts on Africa's ability to produce food crops, though impacts vary extensively by region, climate scenarios used and global circulation model considered (Ringler *et al.*, 2010; Müller *et al.*, 2011; Knox *et al.*, 2012; Ramirez-Villegas *et al.*, 2015). Despite the high variance, and many locations showing increases under some scenarios, both mean and median changes tend to be negative. Different crops are also anticipated to respond differentially to climate change, with a wide range of impacts, which are location and scenario dependent (Table 4.3; Figure 4.10). Maize the staple crop for large parts of Africa will be less severely impacted than wheat, with predicted impacts varying widely, but largely negative. Sugarcane, rice and cassava will be largely unaffected (Knox *et al.*, 2012). Climate change is also anticipated to negatively impact on human access to water resources with rural areas likely to be particularly vulnerable (Kusangaya *et al.*, 2013; Radhouane, 2013).

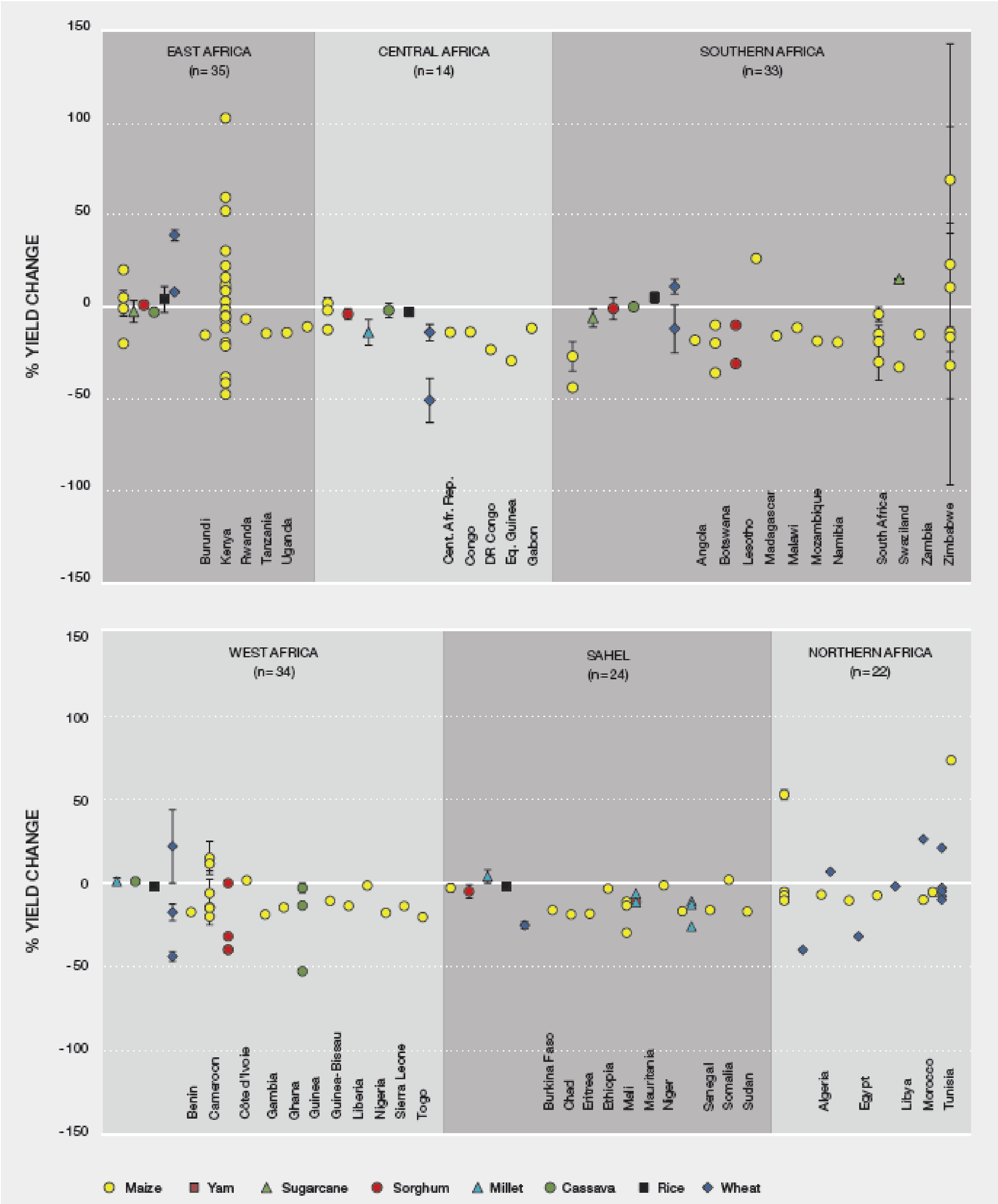


Figure 4.10: Summary of reported mean yield variations (%) in Africa. Data shown are for all observations for each crop type, for all crop modelling approaches, all general circulation models and all time slices. Where published, the confidence intervals for specific studies are shown. Source: Knox *et al.* (2012).

Table 4.3: Summary of reported impacts of climate change on yield (mean and median changes (%)) for all crops, by subregion in Africa (Notes: *n* = Number of reported mean yield changes, which may include several from the same source for different countries or time slices; NS = not significant). Source: Knox *et al.* (2012).

Crop	***n***	**Mean change (%)**	**Median change (%)**	**Crops with significant variations**	***n***	**Mean change (%)**	**Crops with non-significant variation**	***n***
All crops	257	-7.7	-7.0	Wheat Maize Sorghum Millet	37 12 9 23	-12.1 -7.2 -13.0 -8.8	Rice Cassava Sugarcane	43 8 7
Africa	163	-7.7	-10.0	Wheat Maize Sorghum Millet	10 20 6 13	-17.2 -5.4 -14.6 -9.6	Rice Cassava Sugarcane	5 7 3
Southern Africa	33	-11.0	-15.1	Maize	24	-11.4	Wheat Sorghum Sugarcane	2 3 2
Central Africa	14	-14.9	-12.1	Maize	8	-13.1	Wheat	2
East Africa	35	0.4 (NS)	-2.3	_	_	_	Wheat Maize	2 29
West Africa	34	-12.5	-8.4	Maize	19	-7.4	Wheat Sorghum Cassava	3 5 4
Sahel	24	-11.3	-11.5	Maize Millet	13 6	-12.6 -10.6	Sorghum	3
North Africa	22	0.8 (NS)	-7.3	_	_	_	Wheat Maize	10 12

High within and between seasons, as well as inter-annual, variability of rainfall is a natural feature of Africa. However, the frequency of extreme events has increased in the last few decades, which is most likely linked to a changing climate (discussed in more detail below). Changes to the natural conditions, including the natural variation, consequently affect individual organisms, populations, species distributions, and ecosystem function and composition both directly and indirectly (Table 4.4). For instance, amphibians and migratory birds are particularly affected by changes in climate variability (Pounds *et al.*, 2005; Marra *et al.*, 2005: Miller-Rushing *et al.*, 2008; Carey, 2009).

Table 4.4: Indicative ecological responses to climate change and variability.

	Taxon	**Observed changes**	**Observed in**	**Climate link**	**Source**
Phenology	Numerous plant species	Early and significant flowering and maturity	Western Africa	higher temperatures	Clerget *et al.*, 2004

	Butterfly species	Earlier appearance	Eastern Africa	Early rainfall and increased temperatures	van Velzen, 2013
	Amphibians	Occurrence of earlier breeding	Southern Africa	Global warming	Matthews *et al.*, 2016
	Numerous bird species	Earlier singing and spring migration	Southern Africa	Changes in the climate and the advancement of spring	Simmons *et al.*, 2004
Latitudinal and altitudinal range shifts	Shrubs	Expansion of shrubs in previously shrub-free areas.	Southern Africa	Periods of the high rainfall	Tews *et al.*, 2006
The composition of and interactions within communities	Plants	Erosion of the geographical range of desert plants through population declines and dispersal lags	Semi and extreme desert areas	Decreased water availability and increased temperature	Foden *et al.*, 2007
	Browsers and frugivorous	Decreases species richness and assemblage composition of browsers and frugivorous	Western Africa	Availability of moisture.	Klop *et al.*, 2008
The structure and dynamics of ecosystems	Plants	Increased biomass and abundance of woody plants species, often thorny or unpalatable, coupled with the suppression of herbaceous plant cover.	Arid and semi-arid environments of Africa	Rainfall variability	Kgosikoma *et al.*, 2013

4.2.2.3.1. Future climate change dynamics

Temperatures in all African countries are expected to rise faster than the global average (James *et al.*, 2013; Belle *et al.*, 2016; Figure 4.11) with some areas, such as the Kalahari basin warming at close to double the global mean (Engelbrecht *et al.*, 2015). Rainfall projections are less certain, but, rainfall variability is projected to increase over most areas with most models suggest fewer, but higher intensity rainfall events (Myhre *et al.*, 2013). Many areas in Africa are predicted to become drier, despite the global increase in rainfall, especially under high emission scenarios (Myhre *et al.*, 2013). Observed data over the past three decades in East Africa has shown a trend to greater aridity, but this is in contradiction to some long-term forecast (Williams *et al.*, 2011; Myhre *et al*., 2013). The core forest areas of the central Africa may well become wetter with the peripheral woodland and savanna areas becoming drier (de Wasseige *et al.*, 2013). Although in areas of increased rainfall, this may well increase NPP and the provisioning of some ecosystem services, it could have negative biodiversity consequences (de Wasseige *et al.*, 2013).

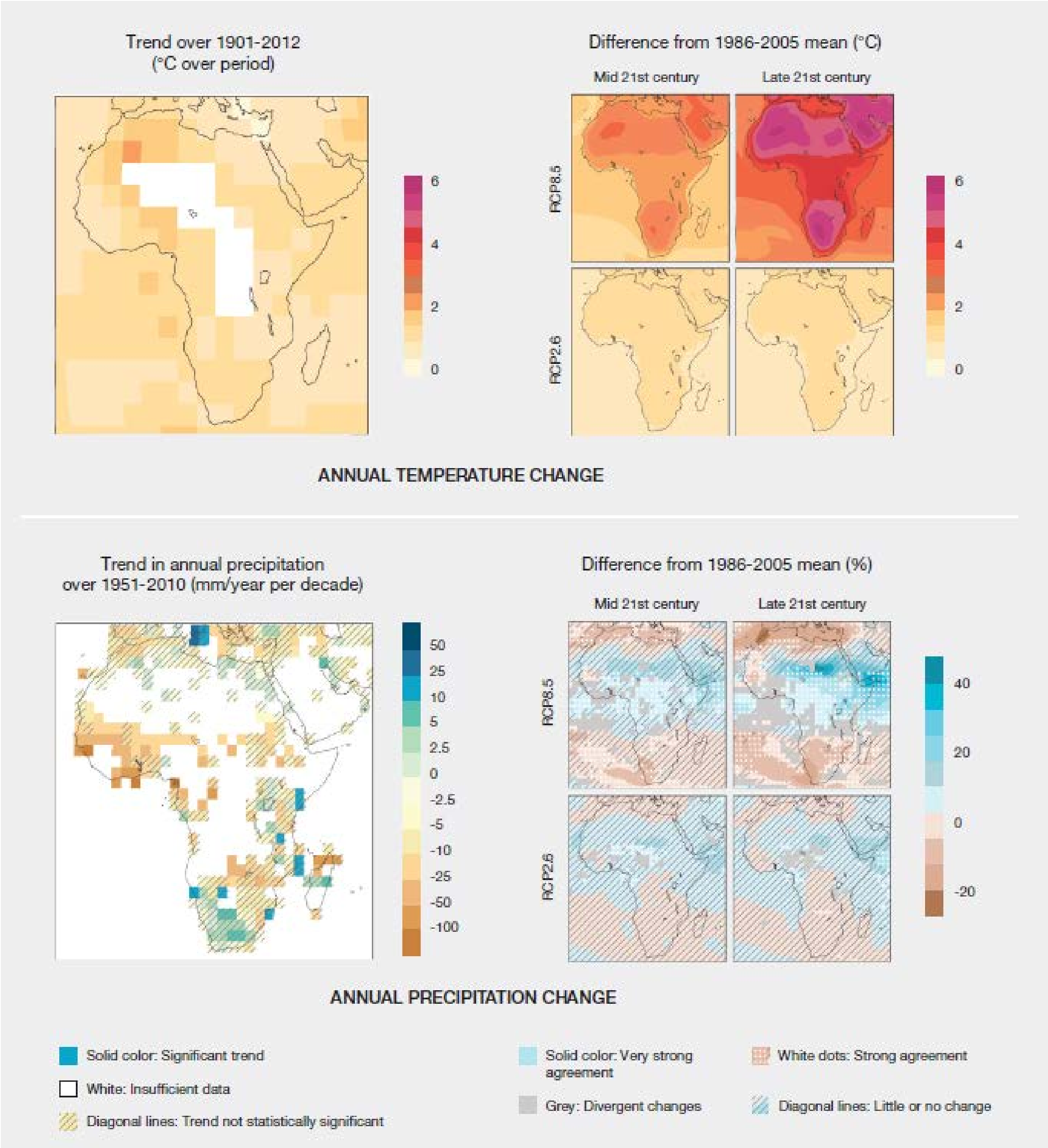


Figure 4.11: "Observed and projected changes in annual average temperature and precipitation. Left panels: Observed annual average temperature change from 1901–2012 (top) and observed annual precipitation change from 1951–2010 (bottom) derived from a linear trend. For observed temperature and precipitation, white areas depict regions which lack sufficient observational data for analysis. Solid colours indicate areas where trends are significant at the 10% level. Diagonal lines indicate areas where trends are not significant. Right panels: CMIP5 multi-model mean projections of annual average temperature changes (top) and average percent changes in annual mean precipitation (bottom) for two time periods (2046–2065 and 2081–2100) under two RCP emissions scenarios. Solid colours indicate very strong agreement amongst models, white dots represent strong agreement, grey areas depict divergent changes, and diagonal lines represent areas with little or no change with respect to current climate variability" Belle *et al.* (2016).

Research shows that climate change will be more pronounced in high-elevation areas than in adjacent lowlands as the former are warming at a faster rate (World Bank, 2008), and that the pace of climate zone shifts will be higher in such regions than in lowlands (Mahlstein *et al.*, 2013). The mountain ecosystems in Africa appear to be undergoing significant observed changes that are likely due to complex climate-land interactions and the climate change (IPCC, 2007).

4.2.2.4. Overexploitation

The overexploitation of natural resources is as a direct result of population growth and is rampant in Africa (Chapter 1; section 1.3.7). This is further compounded by high climate variability and change. Without proper interventions, overexploitation leads to a decline in biodiversity, land degradation, increased vulnerability of rural communities to climate change and poverty.

4.2.2.4.1. Rangeland degradation due to overgrazing

Rangelands makeup 88% of the total area of drylands globally (Lal, 2001) and are important for the livelihoods of people in these areas including in Africa. The rangelands of Africa have evolved under a grazing and browsing by indigenous ungulates, both domestic and wild. Grazing patterns are usually regulated by fodder and water availability as demonstrated by the great migration of zebra and wildebeest in the Serengeti/Masai Mara that is associated with limited degradation of the ecosystem. However, movement of livestock and wild animal populations is sometimes limited by extreme events such as droughts, management and the ubiquity of human settlements. The shift in management of both livestock and wild animals as part of developmental initiatives such as drilling of boreholes in fragile Kalahari ecosystem in Botswana has led to increased animal populations and subsequent increased grazing pressure on rangeland ecosystem. Hence, land degradation is prevalent in grasslands and shrublands, especially in North Africa and East Africa and southern Africa (Nkonya *et al.*, 2016). The extent of degradation in Africa has proven difficult to assess (Wessels *et al.*, 2007; Prince, 2016) and this is attributed in part to poor or lack of rangeland monitoring. So far, it is estimated that 500,000 km^2 of land in Africa is degraded and 16% exposed to soil degradation (Bai *et al.*, 2008; Gibbs *et al.*, 2015) (Figure 4.12). However the methodology used to reach these estimates has been strongly criticised (Wessels, 2009).

The causes of rangeland degradation are complex (Li *et al.*, 2012) and highly contested, but it is generally agreed that degradation is caused by the interaction of biophysical and anthropogenic factors (Lal, 2001; Kiage, 2013). High and prolonged livestock grazing is particularly blamed for rangeland degradation (Palmer *et al.*, 2013) and loss of biodiversity (Watkinson *et al.*, 2001) through the removal of biomass, trampling, destruction of root systems and soil compaction. Overgrazing leads to loss of perennial and palatable terrestrial species, which leaves the land bare or proliferated by less palatable annuals (also known as increaser species), such as *Aristida congesta*, and subsequent loss of biodiversity. In addition, overgrazing creates conducive environment for bush encroachment and invasion of alien species, which eventually replace the herbaceous vegetation and native plants, respectively. In Southern Africa, it is evident that overgrazed rangelands are encroached by *Senegalia mellifera* (formerly known as *Acacia mellifera*), *Vachellia tortilis* (formerly known as *Acacia tortilis*), *Terminalia sericea* and *Dichrostachys cinerea* as reported in Botswana (Moleele *et al.*, 2002), and South Africa (Palmer *et al.*, 2012) and this is accompanied by major shifts in vegetation composition.

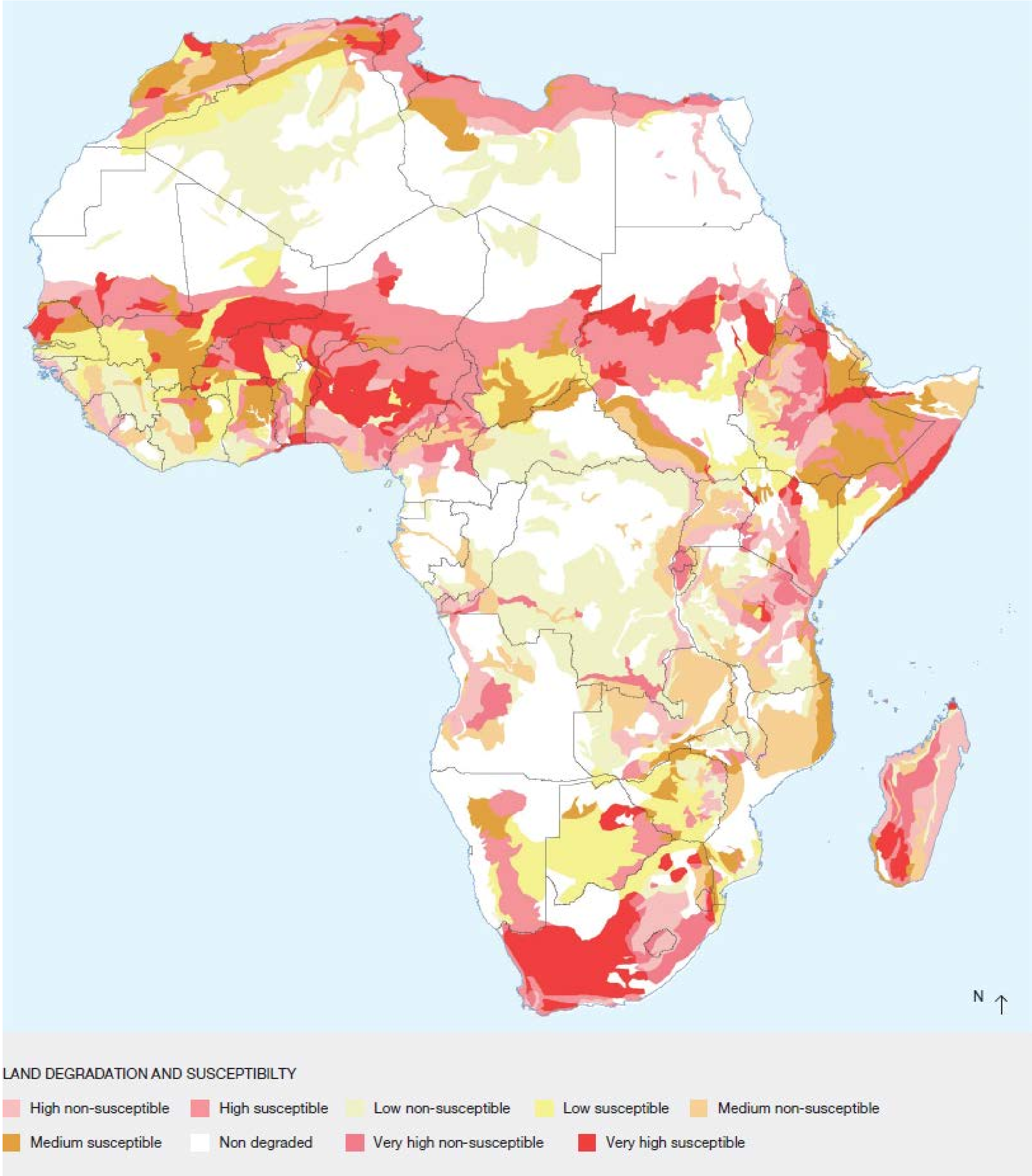


Figure 4.12: Degraded land across Africa. Source: UNEP (2006).

4.2.2.4.2. Overharvesting

Biomass fuel

Wood-based fuels are key energy source for the majority of the African population contributing at least 70% of total energy consumption in sub-Saharan Africa. Charcoal production is a major cause of local overharvesting of trees in many African countries, with many major cities being largely dependent on charcoal as the primary urban fuel resource. The high rate of urban expansion and dependence on biomass as cooking fuels is driving an exponential increase in charcoal demand. Natural forests are overharvested to meet this high-energy demand both in urban and rural areas. As a result, key woody plant species such as *Anogeissus leiocarpa*, *Erythrophleum suaveolens, Prosopis africana*, *Burkea africana*, *Detarium microcarpum*, *Lophira lanceolata, Vitellaria paradoxa* are rare in Togo due to overexploitation for charcoal production (Fontodji *et al.*, 2011). Similarly, Tanzania losses 150,433 hectares of forest per year and the projected charcoal demand indicate that 2.8 million hectares of forests will have been lost by 2030 (Msuya *et al.*, 2011; Figure 4.13).

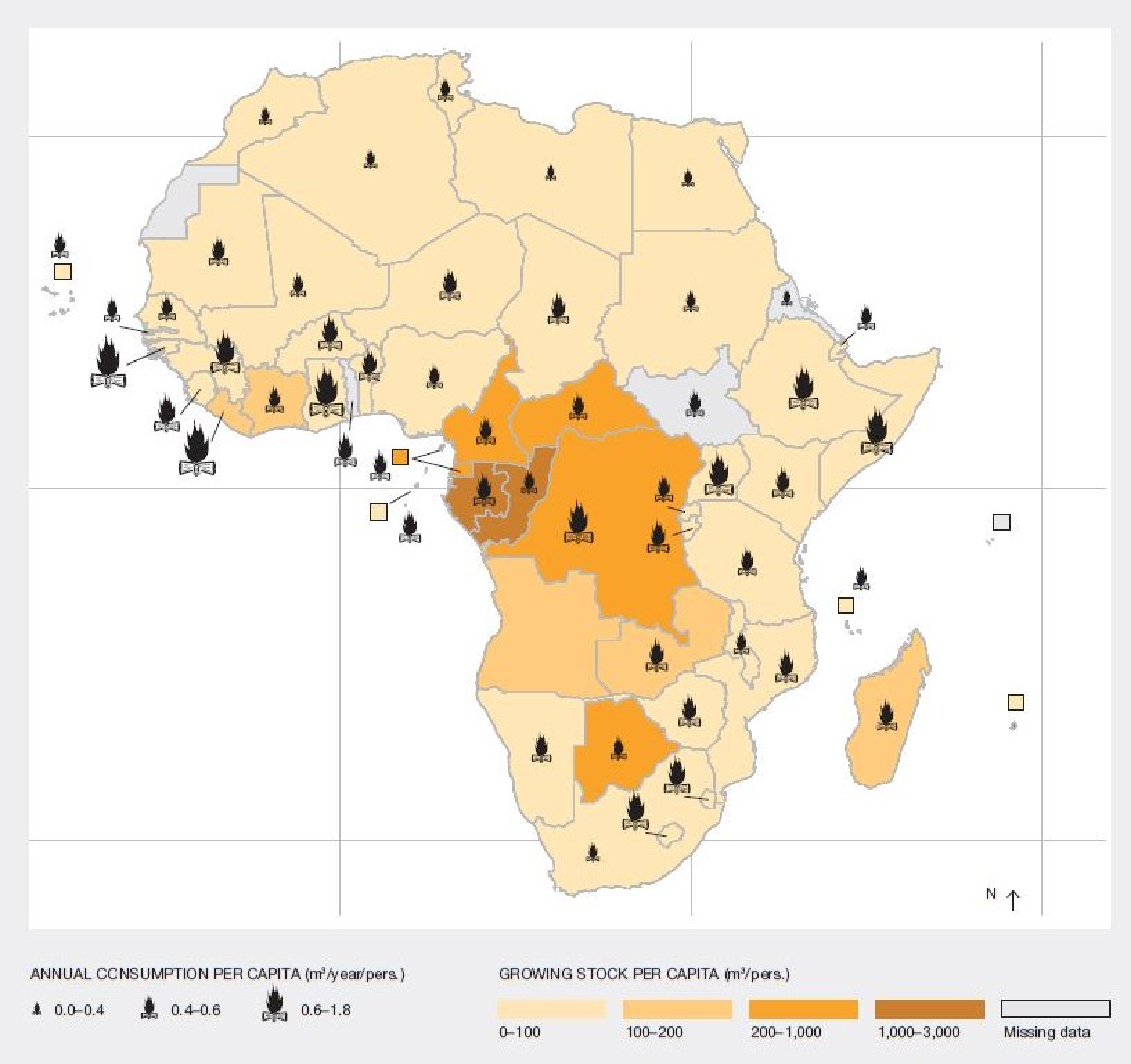


Figure 4.13: Annual consumption of charcoal in Africa. Source: Pesche *et al.* (2016).

<u>Wildlife and other natural resources</u>
Bushmeat, (i.e., the harvesting of wild animals for local consumption or for sale (Cowlishaw *et al.*, 2005)) is a contributor to a decline in mammalian and avian biodiversity throughout most of Africa, particularly in West and Central Africa. Bushmeat is attributed to being a major driver of a decline in animal populations (Bennet *et al.*, 2007) and could well lead to local or total extinction of some species, the great apes being particularly vulnerable (Oates *et al.*, 2000; Obioha *et al.*, 2012). Bushmeat is harvested because it is in effect a more accessible protein resource to communities that are both desperately poor and lacking in dietary protein. Bushmeat hunting has socio-cultural importance (Meinert *et al.*, 2003), and is also regarded as a tastier protein than alternative meat (Obioha *et al.*, 2012). Most bushmeat is harvested from communal forests, and as an open-access resource, is easily over-exploited (Obioha *et al.*, 2012).

Although wildlife has culturally been used as a source of food and materials, the scale of the current harvest is unprecedented and is growing rapidly (Swamy *et al.*, 2014). A 2003 estimate was that between one and 2 million tons of bushmeat was being harvested annually from Central Africa alone (Brown *et al.*, 2003). The issue of consumption of meat from African wildlife requires more holistic examination than current work, which implies that it is driven by local needs, cultures, and poverty. It was demonstrated (Brashares *et al.*, 2004) that the consumption of bushmeat in Ghana at the turn of the century rose in tandem with the rise in the catch by European Union fishing vessels off the coast of West Africa. This rise was in turn, driven by the rise in European Union subsidies to their distant waters fishing fleet. Another study by Knee (2000) found that in Africa, 68% of bushmeat species are hunted unsustainably. This implies that there is a 32% proportion that is considered to be consumed 'sustainably'. This calls for closer examination, because the term 'bushmeat' has a connotation of illegality, in the absence of terminological distinction from the consumption of 'game meat,' which is widespread, particularly in Southern Africa.

Road networks into the dense forests of Central Africa mean that areas that were too remote to be commercially exploited for bushmeat in the past are now accessible and are subject to over-harvesting (Wilkie *et al.*, 1999; Bowen-Jones *et al.*, 2002). In West and Central Africa an estimated 60% of mammalian species are hunted at a rate that is not sustainable (Fa *et al.*, 2002). On the one hand, livestock in many rural African societies has value beyond protein because it can be used as currency for dowry, settlement of disputes and as assets for long-term investment amongst others. On the other hand, bushmeat is regarded by hunters as 'free' protein and is generally the cheapest source of in urban centres (van Vliet, 2012). Rural-urban migration is a strong driver of urban bushmeat demand. The increased urban demand leads to increased commercialization of bushmeat consumption, thus increasing the likelihood of unsustainable harvesting which is exacerbated by the potential to earn income from bush meant sales (Wilkie *et al.*, 1999; Bowen-Jones *et al.*, 2003). Policy formulation and law enforcement in the arena of consumption of wildlife meat in Africa can positively influence sustainable harvest of bushmeat. Use of wildlife resources can be sustainable in cases where hunter-gatherer groups are few and range across large landscapes that they defend as 'their' exclusive territory (Wilkie *et al*., 2016).

4.2.2.4.3. Wildlife poaching

Wildlife plays an important role in both the natural and human worlds: ecologically as keynote species (Bond, 1994), economically as drivers of tourism (Brown Jr, 1993), and culturally as icons of the African continent (Carruthers, 2010). Of these important wildlife species are Rhinos and Elephants, of which their populations are extremely threatened by poaching for ivory (WWF, 2016; Figure 4.14). In Africa, recent surveys suggest that more than 30,000 elephants are killed per year (UNEP *et al*., 2013; Wittemyer *et al.*, 2014), but there is urgent need to for caution in properly assessing these figures and impacts. The global interest in the plight of elephants is has generally been a positive development, but has led to extrapolations, estimates, and conjecture being accepted as paradigm when it comes to poaching. The much-quoted 30,000 per annum figure is actually described by Wittemeyer (2014) as an extrapolation, but is increasingly accepted as empirical fact. Despite global attention to the plight of elephants, their population sizes is shrinking by 8% per year continent-wide, primarily due to poaching (Chase *et al.*, 2016). A survey by Naidoo *et al.* (2016a) revealed that approximately $25 million worth of economic benefits that poached elephants would have delivered annually to African countries via tourism is lost. These lost benefits exceed the anti-poaching costs necessary to stop elephant declines across the continent's savannah areas (Naidoo, 2016b).

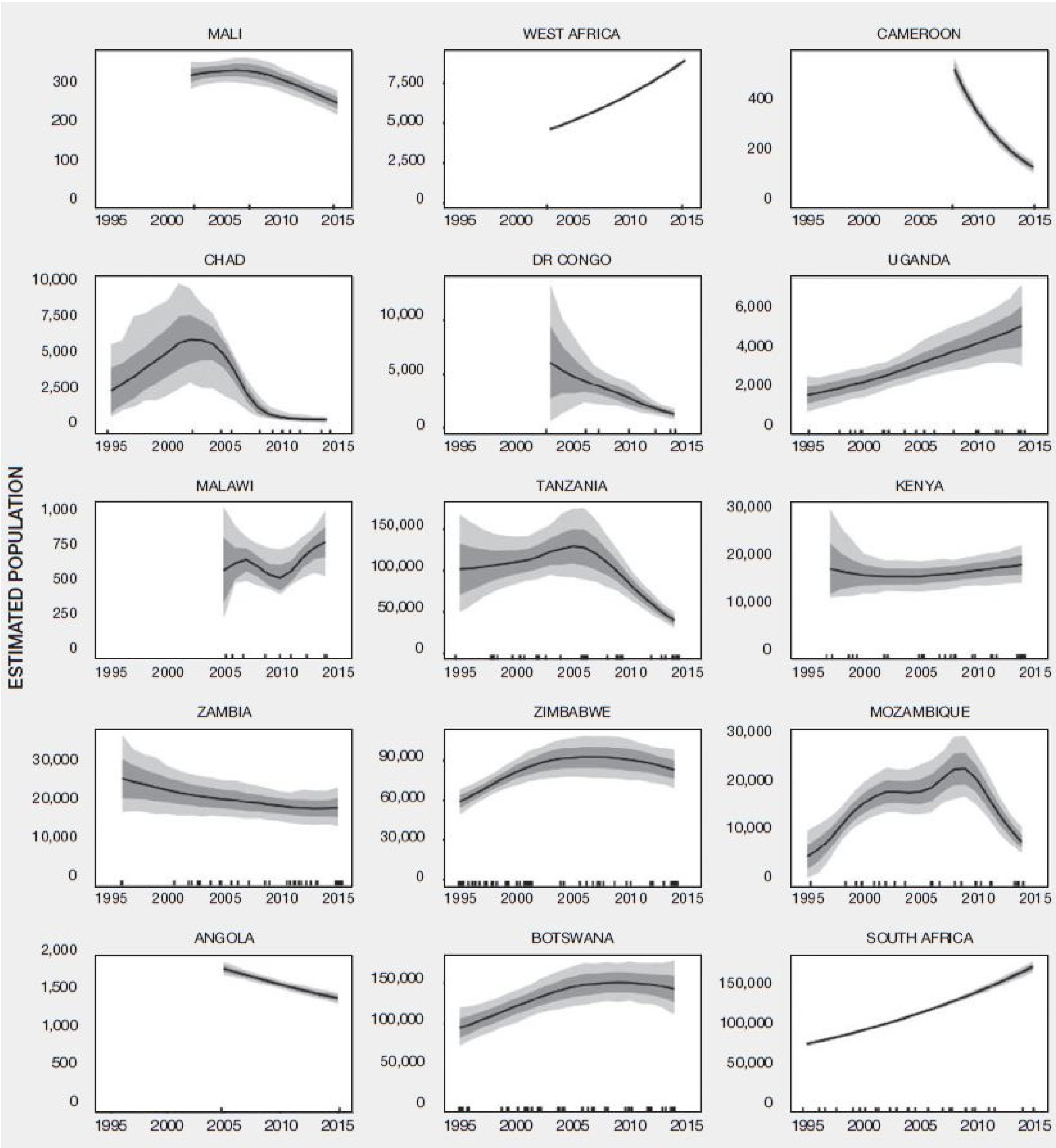


Figure 4.14: Estimated trends in elephant populations for Great Elephant Census study areas with historical data available, 1995–2014. Source: https://doi.org/10.7717/peerj.2354/fig-2

To effectively address the status of elephants, the IPBES Regional Assessment for Africa requires a higher level of resolution so as to avoid the 'trap' of an 'ecosystem services' approach bleeding into biodiversity considerations. The assignment of monetary values 'losses' to poached elephants is flawed in that the values are based on potential commercial gains from the 'legal' (licensed) consumptive use of the same species. This analysis is difficult to apply to countries like Kenya, which don't practice sport hunting, because to photographic tourism, the attraction of elephants to tourists is qualitative, not quantitative. This approach also diminishes the intrinsic value of elephants as part of Africa's natural heritage, and biodiversity as a keystone species. African nations therefore run the risk of valuing their biodiversity exclusively from the perspective of external observers and consumers thereof. This can already be seen in the copious discussions around impacts of 'poaching', without similar treatment of mortality from 'hunting', 'cropping', 'culling', and other 'conservation' and 'management' methods.

Similar to elephants, rhinos have given conservationists cause for concern for many decades, there have been regular reports of their deteriorating status in several countries in particular South Africa (Biggs *et al.*, 2013). South Africa is home to more than 90% of the world's 20,000 white rhino, and 40% (more than 80% together with its neighbour Namibia), of the 5,000 remaining black rhino (Biggs *et al.*, 2013). Yet, poaching in South Africa has, an average, more than doubled each year over the past 5 years (Figure 4.15). The year 2015 was the worst year in decades for rhino poaching-although South Africa reported a small decrease (van Noorden, 2016). If poaching continues to accelerate, Africa's remaining rhino populations may become extinct in the wild within 20 years (Ferreira *et al.*, 2012). The loss of economic value caused by illegal poaching is significant, as is made evident in table 4.5.

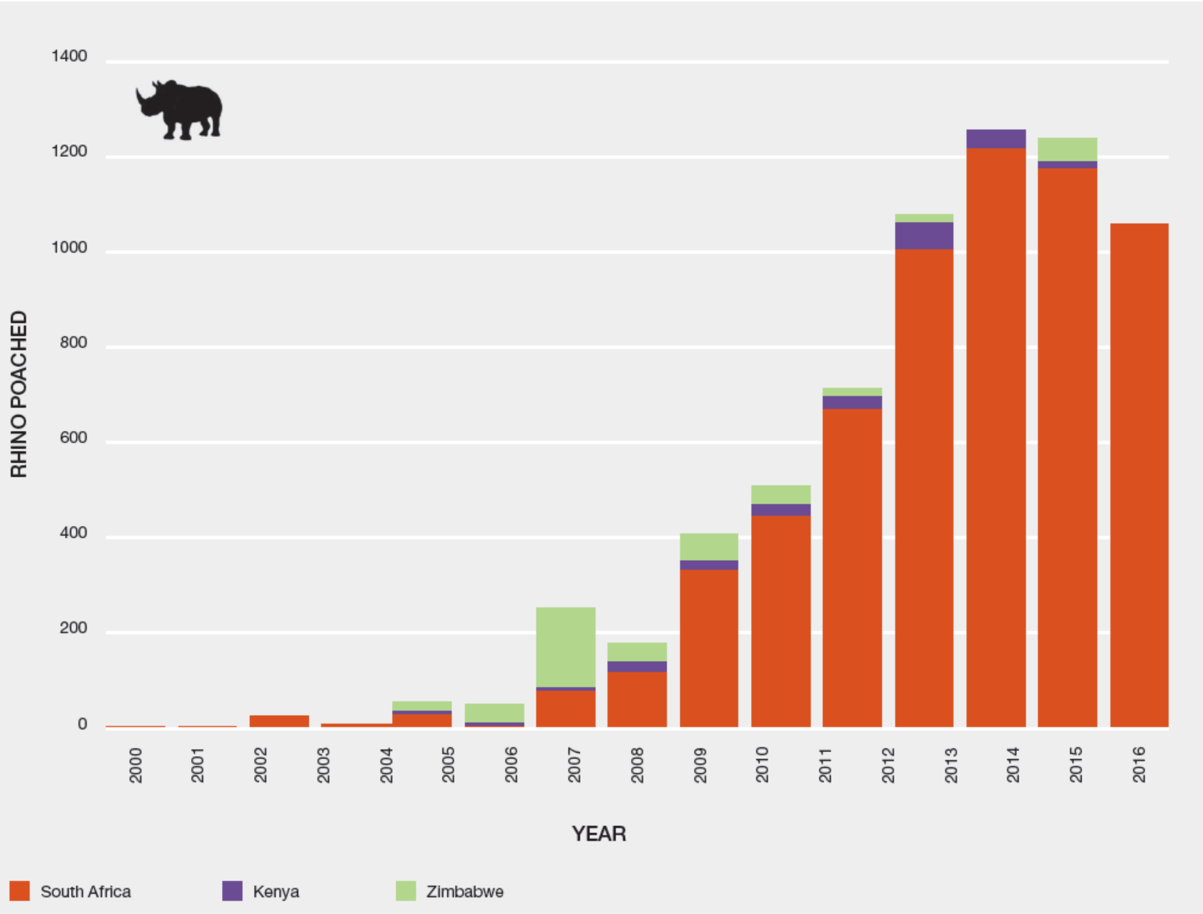


Figure 4.15: Annual rhino poaching in South Africa, Kenya and Zimbabwe since 2000. Data source: http://www.poachingfacts.com/poaching-statistics/rhino-poaching-statistics/

Table 4.5: Economic value lost due to Rhino poaching. Source: Smith *et al.* (2015).

	South Africa	**Namibia**	**Kenya**	**Zimbabwe**
Total loss of potential legal income per year	€133 million	€0.26 million	€4.5 million	€16.9 million
Total loss of natural capital 2006-2012	0	0	0	€360–544 million
Total loss of natural capital per year				€51–76 million
Total economic loss per year	€133 million	€0.26 million	€4.5 million	€68–93 million

4.2.2.4.4. Overfishing

Overfishing refers to extensive fishing beyond considered sustainable levels (FAO, 2010; Nguyen, 2012). Overfishing within inland waters usually occurs for direct consumption or for national economic development, however in most large lakes and deep-sea fisheries, export or foreign vessels drive it. Marine and coastal environments are of ecological and socio-economic importance to African states (Diop *et al.*, 2011). These ecosystems are diverse and provide the continent with valuable goods and services. In South Africa alone the direct contribution of marine and coastal resources to the economy is significant, contributing more than 35% of the gross domestic product (Diop *et al.*, 2011). Local and global demand for fish and rapidly growing populations that depend on freshwater and marine fisheries are the main causes of overfishing in Africa (Arthurton *et al.*, 2006; Diop *et al.*, 2011).

As the world's human population grows, so does the demand for marine food sources and the number of individuals whose livelihoods fully or partly depend on it (Garcia *et al.*, 2010). In North Africa, a subregion with very limited freshwater resources, overfishing is has impacted aquatic resources including 5 species of freshwater fish and 23 aquatic plants, 6 of which are listed as threatened under the IUCN Redlist (IUCN, 2013). In East Africa, many villages around the shores have free access to coastal waters and with this easy accessibility, overfishing tends to occur to support increasing demands on resources to support poor families (McClanaban, 1987). Majority of fish stocks in West African waters is depleting due to overfishing and other drivers (Nguyen, 2012; Box 4.6). Increased demand of fish from foreign nations such as European Union, Japan, Russia and China and government's greed and corruption in West Africa have the greatest influence in overfishing (Nguyen, 2012). The overfishing leads to the conflicts between the artisanal and commercial fisheries due to the competition for the same fishing grounds (physical conflicts) and/or common resources (technological conflicts). These conflicts affect the ecosystems and the well-being of the fishermen (Djama, 1992; Bennett, 1998). Institute for security studies (2007) reported that many African countries will have collapsed fisheries and degraded marine environments in the near future. This is not too far from the truth since the British Marine Resources Group reported in 2005 that South Africa harvested about 320,000 tons of Patagonian Toothfish within 2 years while the Total Allowable Catch set by the government was 450 tons/year. It is thus clear to see that fisheries are being overexploited.

Box 4.6: Case study: Overfishing in Senegal

In Senegal fish is the main source of protein (UNEP, 2002; Iossa *et al.*, 2008; Nguyen, 2012) and accounts for about 75% of all protein consumption (UNEP, 2002; Nguyen, 2012). Consumption is by both the rural and urban populations because fish is affordable compared to mutton and other protein sources (Iossa *et al.*, 2008). Most people in Senegal live below the poverty line (Iossa *et al.*, 2008) and therefore fish is essential for people in this country. Fisheries sector generated about 600,000 direct and indirect jobs in Senegal (UNEP, 2002), for this reason fishing is important for livelihoods. Overfishing which leads to depletion of marine ecosystems is a threat to, not only biodiversity of marine ecosystems, but also to Senegalese people who depend on these ecosystems for nature's contributions to people (Iossa *et al.*, 2008; Nguyen, 2012). Most of the fish catches are used for direct human consumption (Nguyen, 2012). Eighty percent of fish exports that originate from Africa are supplied to the European market, and 66% of the total exports from Senegal are supplied to Europe (Nguyen, 2012).

4.2.2.5. Invasive Alien Species

Invasive alien species are considered one of the most serious threats to the conservation of biodiversity and ecosystem services in Africa and, according to IPBES glossary, are defined as animals, plants or other organisms introduced directly or indirectly by people into places out of their natural range of distribution, where they have become established and dispersed, and are generating a negative impact on local ecosystems and species.

4.2.2.5.1. Treaties and conventions for a regional collaboration to deal with invasive alien species in Africa

Africa has recognised the importance of controlling the introduction of damaging invasive alien species through several agreements and protocols. The African Union's New Partnership for Africa's Development, in its Framework Action Plan for the Environment, identifies Invasive Alien Species (IAS) as one of its core program areas. In addition, the African Convention on the Conservation of Nature and Natural Resources, adopted in 1968, required Parties to prohibit the entry of "zoological or biological specimens, whether indigenous or imported, wild or domestic" that may cause harm to protected areas. Moreover, the Protocol concerning Protected Areas and Wild Fauna and Flora in the East Africa Region (UNEP, 1985) called for the adoption of appropriate measures to prohibit the intentional or accidental introduction of IAS, which may cause significant changes to the subregion. The World Trade Organization Sanitary and Phytosanitary Agreement empowers individual country's plant protection organisations to draw up measures that are strong enough to prevent the introduction of pests that may arise through trade.

Other protocols developed by subregional bodies also address some aspects of controlling IAS include the Treaty for the Establishment of the Eastern African Community, Treaty of the Southern African Development Community, and the Treaty establishing the Common Market for Eastern and Southern Africa. The African Convention on the Conservation of Nature and Natural Resources required parties to strictly control the intentional and accidental introduction of invasive alien species, including modified organisms and to endeavour to eradicate those already introduced where their consequences are detrimental to native species or to the environment in general. The Forest Invasive Species Network for Africa was created in 2004 to coordinate the collation and dissemination of information relating to forest invasive species in sub-Saharan Africa for sustainable forest management and conservation of biodiversity. Economic tools such as taxes, subsidies, permits are not well suited to deal with the problems caused by invasions. Molecular biology tools and global positioning system-enabled tools are utilized in diagnostics and surveillance. Conflicts of interest may appear about IAS at local scales. While some authors consider that claims about the benefits of invasive alien species are unsubstantiated (Witt, 2010), some studies reveal that benefits to people may also be possible (see case study below). Scenarios on the extension of invasive alien species remain scarce in Africa. Maundu *et al.* (2009) suggest that nearly 50% of Kenya's surface area has a 30% or more probability of being invaded by *P. juliflora*.

Box 4.7: Case study: conflicts of interest on plant Invasive Alien Species (IAS)

Invasive alien species may provide benefits to people through both commercial and non-commercial uses, thus causing policy dilemmas. Local populations are more like to come to terms with invasive alien species especially when they benefit from them. This may generate conflicts of interest between local communities and governments. Examples include the use of prickly pear (*Opuntia ficus-indica*) in South Africa (Shackleton *et al.*, 2011), Black Wattle (*Acacia mearnsii*) in South Africa (Shackleton, 2007; Aitken *et al.*, 2009), Mesquito (*Prosopis juliflora*) in Ethiopia (Mwangi *et al*., 2005), *Acacia mearnsii* on Reunion Island (Tassin *et al.*, 2012) and many species in Madagascar which are used as medicinal plants (Kull *et al.*, 2011). Malagasy people have rapidly developed a new local knowledge on the medicinal uses of invasive plants. However, conflicts of interest evolve, and the balance between benefits and loss can change. In Lake Baringo, Kenya, local people have recently come to consider Mesquito beneficial for production of charcoal. Conversely, on the Highlands of Madagascar, Mimosa (*Acacia dealbata*) is still considered by the rural populations as beneficial (Kull *et al.*, 2007). The use of IAS may represent an efficient control means, but such an option seems difficult to legitimate in the absence of clear national policies and strategies in the management of IAS (Tessema, 2012).

4.2.2.5.2. The main types of invasive alien species impacting biodiversity and ecosystem services in Africa

Compared with other continents and cultures, invasive alien species remain poorly documented in the African continent (Witt, 2010), except East Africa, the Republic of South Africa and the islands of western Indian Oocean (Mauritius, Seychelles, Reunion Island). Invasive alien species threaten all subregions in Africa and affect wetlands, forests, drylands, freshwater bodies, estuaries, deltas, marine, coastal and other ecosystems, mainly where areas have been disturbed by human activities. They occur in all major taxonomic groups, including viruses, fungi, algae, plants, fish, amphibians, reptiles, birds and mammals. Within plants, ornamental invasive alien species represent the highest proportion of invasives (Tassin *et al.*, 2007). The IAS pressure is regularly increasing with time, as shown in Kenya (Stadler *et al.*, 1998), on Reunion Island (Tassin *et al.*, 2006) and in Zimbabwe by Maroyi (2012), who has recorded from herbarium records the strongest increase of IAS records from 1941 to 1960.

Beyond the orthodox definition of invasive alien species restricted to introduced species, native species can also be invasive (Valéry *et al.*, 2009). The famous Red Billed Quelea (*Quelea quelea*) is native to Africa but takes advantage of native or artificial grasslands and seed crops to establish in millions of individuals. On poor and eroded soils of humid regions, as Batéké plateau, coast lowlands of Gabon, or slopes of western Indian Ocean islands, the fern *Dicranopteris linearis* seems to forbid the natural succession process (Kueffer *et al.*, 2004). On Mayotte, the native liana *Merremia peltata* colonizes the forest canopy, making them to collapse under their heaviness and traction (Tassin *et al.*, 2015). In humid forests of Gabon, some *Zingiberaceae* are assumed to compromise the regeneration of other native plant species. Bush encroachment by native undesired woody species has an estimated extent of 26–30 million hectares in Namibia and 10–20 million hectares in South Africa (Bester, 1999; Kraaij *et al.*, 2006).

4.2.2.5.3. Assessment of impacts of invasive alien species on biodiversity and ecosystem services in Africa

Invasive alien species affect biodiversity and nature's contributions to people (e.g., food production and water supply, waste assimilation, recycling of nutrients, conservation and regeneration of soils, pollination of crops, seed dispersal) globally and regionally (African continent including islands) and have significant impacts on the economy and livelihoods (including on human health, water security, fire and the productive use of lands). For instance, white cassava mealybug and larger grain borer pose direct threats to food security. The impacts of invasive plants is also high in the continent because more than 80% of the population comprises small-scale farmers who are dependent on natural resources for their survival (Witt, 2010). For instance, in the lowlands of Ethiopia, *Parthenium* (*Parthenium hysterophorus*) is perceived as the most important weed by 90% of the rural population (Tamado *et al*., 2000). It prevents germination through allelopathy and competition in crops and natural stands. There is a need to understand the status, trends, distribution, impact, control measures and the policy options for control and eradication of invasive alien species.

Box 4.8: Case study: Costs of Invasive Alien Species in South-Africa

Invasive alien species cover about 10% of South Africa and use 3.3 billion m^3 of water/year (the equivalent of about 7% of all water resources) (Department of Water Affairs in South Africa, 2010); they mainly consist in Australian trees and shrubs and Northern Hemisphere pine species which have been introduced into habitats with suitable climatic and edaphic conditions for growth and spread. Moreover, 2.95% of the runoff is a direct consequence of plant invasions. In a water scarce country, where demand exceeds available water in almost all catchments, this added stress is a major concern (Le Maitre *et al.*, 2016). The Convention on Biological Diversity estimated that Africa spends close to $60,000 million/year to control invasive alien species (Boy *et al.*, 2013). In the South African Cape Floral Kingdom, invasive tree species cost $40 million/year for a control program (Matthews *et al*., 2004). The total cost of invasion on the Agulhas Plain alone amounts to $11.75 billion (van Wilgen *et al.*, 2001). In the Western Cape Province, invasions have allegedly reduced the value of Fynbos (Western Cape Mediterranean scrub vegetation) ecosystems by over $11.75 billion (van Wilgen *et al.*, 2001). Control of invasive rats and mice costs the world roughly $2.7 billion/year (Pimentel *et al.*, 2001).

Invasive alien species have a strong impact on rural production and ecosystem services in Africa (Table 4.6). Yet, economic assessments of invasive alien species impacts have been rarely conducted outside South Africa (Box 4.8). A recent assessment in six East African countries (Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda) has provided an estimated annual production losses to smallholders, due to some invasive alien species on maize (spotted stem borer, maize lethal necrosis disease, *Parthenium*), bean and pea (leaf-mining flies), and tomato (tomato leaf-miner), estimating losses of between $894.4 and $1099.7 million (Pratt *et al.*, 2017). The economic impacts of water hyacinth (*Eichhornia crassipes*) infestations in seven African countries have been estimated at between $20 million and $50 million annually (Joffe *et al.*, 1997); impact costs across Africa may exceed $100 million annually (Boy *et al.*, 2013). The environmental impact of invasive alien species in Africa on the wilderness remains poorly documented. Invasive alien plant may have deleterious effects on wilderness, and the impact of Australian plant species on the vegetation of Fynbos has been deeply documented (Witkowski, 1991; Moll *et al.*, 1992; Holmes *et al.*, 1997). Conversely, it may commonly provide new resources or habitats for native animals in Africa, for instance African sunbirds (Geerts *et al.*, 2009). So, the impact of IAS is complex because they may have both positive and negative environmental impacts at the same time, depending on the context. For instance, in Mayotte, *Acacia mangium* controls erosion on highly degraded lands (paddza), but also facilitates fires (Kull *et al.*, 2008). In South Africa, *Acacia melanoxylon* also produces opposite effects (Geldenhuys, 1986).

Table 4.6: Most important invasive alien species in Africa, and their impacts.

Species	**Impact**	**Sites of Africa**	**References**
Plant species			
Acacia sp. (Australian acacia species)	Invade fallows and natural areas	South Africa (Cape Province); Reunion Island	Witkowski, 1991; Moll *et al.*, 1992; Holmes *et al.*, 1997; Tassin *et al.*, 2012
Chromolaena odorata (Siam weed)	Has taken over pastures, farmlands and wilderness areas; affects plant communities and disrupt forest successions; may seriously impact the populations of western lowland gorillas in Southern Cameroon	Sub-Saharan Africa, including the Serengeti-Masai Mara area	van der Hoeven *et al.*, 2007; Boy *et al.*, 2013
Eichhornia crassipes (Water Hyacinth)	Covers large areas of lakes and wetlands and interferes with navigation, irrigation and water supply; affects fish breeding patterns particularly cichlids	Whole Africa	Wanda *et al.*, 2001; Waithaka, 2013;
Lantana camara (Lantana)	Common in fallows and plantations; has invaded almost every Protected Area; facilitates fires	Southern and eastern Africa	Boy *et al.*, 2013
Leucaena leucocephala (Leucaena)		Sub-Saharan Africa.	Boy *et al.*, 2013
Mimosa pigra (Giant Sensitive Plant)	Invades wetlands, swamps and floodplains	Sub-Saharan Africa	Witt, 2010; Boy *et al.*, 2013
Parthenium hysterophorus (Parthenium weed)	Impacts on crop yields and wilderness areas; contain potents allergens affecting grazing and browsing animals; taints the milk	Eastern Africa	Witt, 2010; Boy *et al.*, 2013
Prosopis juliflora (Mesquite)	Invades pasture lands and has become a noxious weed	Ethiopia, Kenya	Mwangi *et al.*, 2005; Witt, 2010; Tessema, 2012
Salvinia molesta (Kariba Weed)	Blocking waterways and diminishing fish stocks.	Whole Africa	Boy *et al.*, 2013
Senna spectabilis (Cassia)	Dominates understorey in forested areas, and affects the food supply of chimpanzees	Tanzania, Uganda	Turner, 1996; Nashida, 1996; Boy *et al.*, 2013
Striga sp. pl. (Striga)	Invade crops (cereal and legumes)	Whole Africa	
Animal species			
Acridotheres tristis (Mynah)	Competition with native birds	West Indian Ocean islands	

Procambarus clarkii (Louisiana crayfish)	Disappearance of submerged vegetation, freshwater crabs, predation of fish eggs and tadpoles; damage to fish catch and disruption of fishing gear; destabilization of freshwater otter prey base; damage to dam and reservoirs	Freshwater ecosystems of Eastern and Southern Africa	Howard *et al.*, 2003 Ogada *et al.*, 2009
Lates niloticus (Nile Perch)	Reduced by half the native haplochromine cichlid fish species of Lake Vicotria through predation	Lake Victoria	Ogutu-Ohwayo, 1999 Pringle, 2005
Oncorhynchus mykiss Rainbow Trout)	Disappearance and local extinction of endemic mountain catfishes		Cambray, 2003; Woodford *et al.*, 2004
Rattus rattus (Rat)	Impact on crops, and on native flora and fauna	Whole Africa	

The current pattern suggests the number of invasive alien species in African countries have increased markedly in the last decades, with 207 identified in South Africa, 104 in Tanzania, 107 in Kenya and 103 in Morocco alone (see Figure 4.16(b)). South Africa is the only country in sub-Saharan Africa having a sustained and funded program to deal with invasive alien species (Boy *et al.*, 2013), specifically plant species. It has set up a large Working for Water Program which has cleared about 1 million hectares of land invaded by alien plants, offering job to 20,000 people from disadvantaged communities (Department of Water Affairs in South Africa, 2010; Boy *et al.*, 2013). More efforts are needed to combat invasive alien plants across the continent in order to improve benefits African peoples might receive from nature's contribution to people.

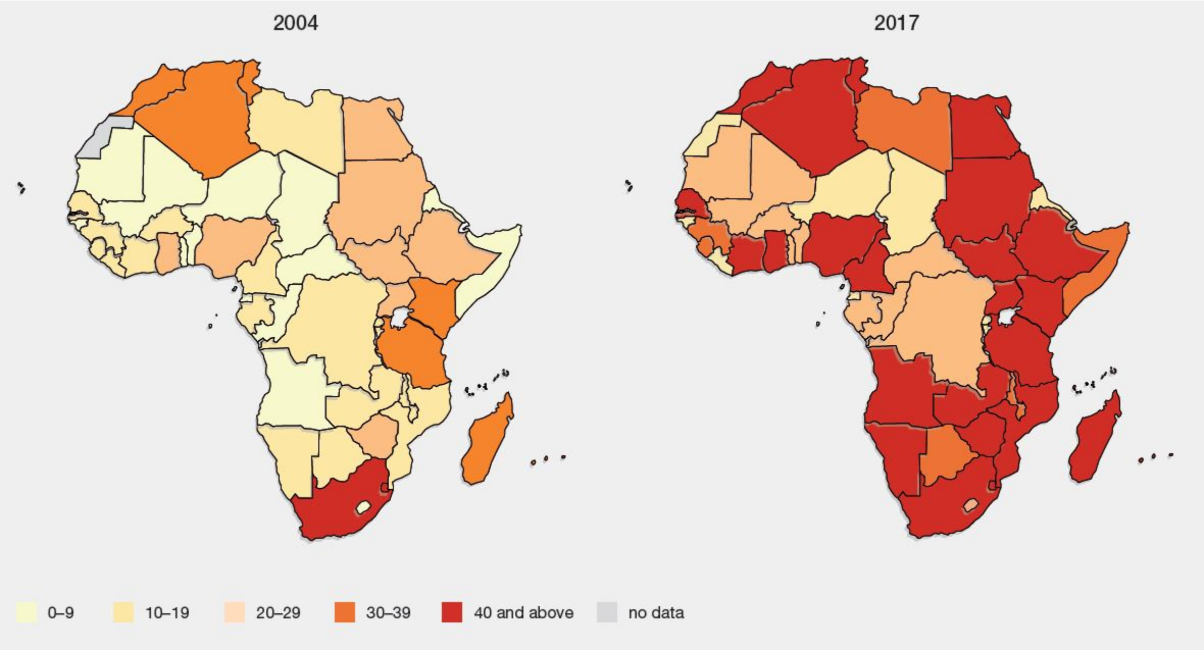


Figure 4.16: The incidence of invasive alien plants in Africa in 2004 and 2017. Data sources: For 2004, Chenje *et al*. (2006) and for 2017, http://www.iucngisd.org/gisd/

4.2.2.6. Pollution (soil, water, air)

The section assesses literature regarding extent and patterns of soil, water and air pollution as drivers for changes in biodiversity and nature's contributions to people. Such assessment is based on the spatial location bearing in mind Africa's existing ecological zones. Pollution causes could either be anthropogenic or natural with the former escalating at an alarming rate in Africa. Pollutants that affect biodiversity in Africa are characterized as either chemical, physical or biological and the spatial considerations are evaluated with regard to whether the pollutants are air, water or soil pollutants; point or non-point source with a subregional focus.

4.2.2.6.1. Soil Pollution

Non-point anthropogenic chemical contaminants of soil that are of great concern in Africa include the agrochemicals whose great rise has been mainly as a response to need to feed the growing population. This is worsened by the changing lifestyles of a large majority of Africans, from agricultural to urban dwelling persons, whose labour input in the farmlands have to be replaced with mechanization and application of herbicides (Freire *et al.*, 2014). The current urban population is about 40%, an increase from 15% in 1960 and is expected to soar to 60% by 2050 (Obeng-Odoom, 2013). Use of increased varieties and quantities of pesticides have been recorded in a number of countries concomitant with urbanisation, population growth, and expansion of agriculturally dependent economies in Africa (Nonga *et al.*, 2011; Quinn *et al.*, 2011; Byerlee *et al*., 2013). Changes from hand-held tools to use of machinery including aerial spray of pesticides and agrochemicals in general confer worse effects on biodiversity. This is especially true because the resultant drift affects more non-target organisms. This has been reported for wildlife in Maasai Mara of Kenya that neighbours large-scale wheat farms, (Lambert, 1997; Schulz *et al.*, 2001; Muchane *et al.*, 2012; Odido *et al.*, 2013).

The fate of the pesticides is modified by climatic conditions and in Africa these present challenges that may be different from those in better-studied regions of the world. The stable breakdown products of the widely studied p,p'-(dichlorodiphenyl)-1,1,1-trichloroethane (DDT) and a number of other widely used pesticides such as chloracetanilides are found to play more important roles in the environment than their parent compounds in Africa thus causing toxicities that have longer term and probably more devastating effects on living organisms (Kiflom *et al.*, 1999; Karlsson *et al.*, 2000; Osano *et al.*, 2003). In addition, a number of pesticides, which have already been banned or have restrictions in their usage (because of their toxicity in the environment) in other parts in the world are still used in large and increasing quantities in Africa (Wandiga, 2001), an area that invites formulation and application of sound policies. Of great concern and interest in Africa are the chemicals covered in the Stockholm Convention on Persistent Organic Pollutants, especially the DDT. The need to safeguard human health against malaria has attracted controversial consideration of continued use of DDT albeit under strict conditions including obligations to investigate use of alternatives in Africa (Anon, 2004; Bouwman, 2004).

A number of restricted persistent organic pollutant pesticides including aldrin, dieldrin, endrin, heptachlor and toxaphene have been used beyond the effective dates of ratification of the convention by the user countries in Africa and their residues have been found in various compartments in the environment (Quin, 2011; Barnhoorn *et al.*, 2015). There is a rising concern of persistent organic pollutants produced unintentionally through a number of anthropogenic processes such as compounds that include the polychlorinated dioxins, polychlorinated dibenzofurans and polychlorinated biphenyls, and hexachlorobenzene. The processes associated with these include several municipal and industrial combustion processes, application of chlorine for bleaching in pulp production and thermal processes in metallurgical industry most of which are on the rise in Africa.

In addition, stockpiles of unused chemicals pose grave danger of leakages or irresponsible disposal to the environment. Urgent action needs to be taken to identify, manage and destroy stockpile while taking care not to allow recycling or reuse of the stockpiles and where possible carry out remediation of contaminated sites. An initiative like the African Stockpiles Program approved by the Global Environmental Fund and implemented by the World Bank may relieve African nations of the stockpiles but it has faced challenges of laying down groundwork logistics for its implementation (Bouwman, 2004). Salinization of soil, common consequence of irrigation programs, deserves more attention, given the increasing demand for increased acreage of irrigated land across the continent (Hussain *et al.*, 2004; Orindi *et al.*, 2005; Oweis *et al.*, 2006).

Industrial – based soil contaminants are of growing concern because of the increase ownership of motor vehicles, mining, and industries in general. Vehicular exhaust pollutants comprising polyaromatic hydrocarbons and tetraethyl lead (which is now in decline due to conversion to unleaded fuel) are deposited on the ground along the motorways and are increasing quantities of toxic metals deposited on the ground (Olade, 1987; Davies *et al.*, 2005). Of particular concern is increase in soil pollution with increasing activities in both artisanal and large-scale mining, a situation which is worse when compared to mining activities in developed nations and one that is attributable to improper management of the tailings (Narendrula *et al.*, 2012). The biological pollutants of the environment is a new phenomenon brought to fore especially with the introduction of biotechnology in agriculture. There is a rising worry that new genetic materials may be introduced in the environment with devastating consequences to existing species.

Pollution from natural causes may occur after eruptions of the numerous active volcanic mountains in Africa exemplified by the frequent rage of the Virunga Mountains whose plumes are displaced over a long distance and causes changes the quality of rainwater including acidity (pH up to 2), increase concentrations of Fluoride (up to 2,400 mg/L), Chloride (up to 1,750 mg/L) and Sulphide (up to 10,000 mg/L). These events have detrimental effects on the equatorial rain forest, and likely impose possible strain on the dwindling populations of gorillas (*Gorilla beringei*) (Delfosse, 2005; Plumptre *et al.*, 2007; Vaselli *et al.*, 2008). Specifically, the gorillas whose censual population stood at a finite 360 in 2003, face dual (anthropogenic and natural) challenges such as fragile and explosive political strife and raging volcanic activities of the Virunga Mountains (Kalpers *et al.*, 2003; Vaselli *et al.*, 2008; Gray *et al.*, 2010).

4.2.2.6.2. Water Pollution

Alongside the pesticides, an increased application of inorganic nutrients including the phosphate and nitrates, has been witnessed and consequences of eutrophication of downstream water bodies have been a concern (Saad, 1980; Oberholster *et al.*, 2009; Nyenje *et al.*, 2010; Van Ginkel, 2011). Besides the non-point source draining of agrochemicals (pesticides and nutrients) into the water bodies, industries and the growing urban centres in the African continent are already exerting considerable pressure on the ecosystems of both marine and freshwater bodies. Emergence of dead zones, sequel of nutrient fed into the sea from agricultural catchment and rise in dissolved carbon has been on the rise worldwide (Lavelle *et al.*, 2005; Diaz *et al.*, 2008) and the African seas will not be exceptions especially in areas draining regions with escalated intensive agricultural practices. This is worsened by the well-known natural coastal upwelling associated with western boundary of landmasses, which are productive but unfortunately suffer for severe hypoxia (<0.5 ml O_2/litre), a condition already affecting the south

Atlantic west of Africa and other parts of the world (Díaz *et al.*, 2008). So far, the total export of nutrients (nitrogen and phosphorous) by the African rivers increased by 10 to 80% (Yasin *et al.*, 2010) and rivers draining ivory Coast's mainland are already oversaturated with CO_2 (Kone *et al.*, 2009). Evidence that Africa aquatic ecosystems are already suffering the wrath of application of pesticides upstream abounds (Odada *et al.*, 2004; Hecky *et al.*, 2006). Toxic levels of pesticides capable of altering endocrine, survival and health of aquatic organisms have been found in a number of lakes and rivers in Africa (Mugachia *et al.*, 1992; Kidd *et al.*, 2001; Ezemonye *et al.*, 2008; Okeniyia *et al.*, 2009). The lack of innovative solutions and unclear policy guidance has led to reintroduction of Dichlorodiphenyltrichloroethane (DDT) into farming systems and for mosquito control in many countries in Africa in the recent past to remedy recalcitrant continental problems without regards to environmental quality (Cork *et al.*, 2005).

Pollution of the water bodies with heavy and toxic metals could either be from non-point agricultural sources, e.g., cadmium contaminated agricultural fertilizers or point sources like the industrial and municipal effluents. High concentrations of the toxic metals including mercury, lead, cadmium, and copper have been established in both benthic and pelagic aquatic organisms in lakes and rivers of Africa (Campbell *et al.*, 2003; Kishe *et al.*, 2003; Ramlal *et al.*, 2003; van Aardt *et al.*, 2004; Campbell *et al.*, 2005). Industrial and municipal derived contaminants including the polychlorinated biphenyls (PCB) and dibenzofurans; Dioxins and dioxin like PCBs; and endocrine disrupting compounds have been detected in water, sediments and tissues in South Africa, Lakes Malawi and Victoria, and River Nile among other water bodies (Bootsma *et al.*, 1993; Bootsma *et al.*, 2004; Coimbra *et al.*, 2007; El-Kady *et al.*, 2007; Mdegela *et al.*, 2010; Olujimi *et al.*, 2010; Wepener *et al.*, 2012; Ssebugere *et al.*, 2013; Omwoma *et al.*, 2015). There is already a growing evidence of the ramifications of these chemical on health especially reproduction aquatic organism in a number of water bodies (Barnhoorn *et al.*, 2004; Manickum *et al.*, 2014). With the current rise in urbanisation and aspirations for industrialisation captured in various visions of the African countries, it is expected that emission of metals, chlorinated hydrocarbons, and endocrine disruptors into the water bodies will increase.

Physical pollutants of the water bodies include suspended matter arising from soil erosion (a consequence of poor land-use management) and thermal pollution due to emission of inadequately cooled water from the industries along the lakes, oceans and rivers in Africa. In a number of East African lakes namely Victoria, Tanganyika, Malawi, Albert, Kivu and Edward, thermal pollution characterised by a circa 0.2–0.7^{o}C rise in temperature, over a period of 6 decades, has been attributed to climate change (Vollmer *et al.*, 2005; Bates *et al.*, 2008). The rise in temperature influences the thermal stratification and internal hydrological dynamics of the lakes. The resultant increased stratification reduces water movement across thermocline thereby inhibiting upwelling and mixing that provides essential nutrients to the food web. The rise in the temperature in water may enhance degradation of organic pollutants and is known to increase alkylation of mercury (Bates *et al.*, 2008).

There has also been a burgeoning use of plastic in the continent, due to plastics desirable qualities of cheapness, durability, lightness and low mass. The consequence of this is high rates of contamination of the environment with plastics, in some cases up to 10% of the solid waste contaminants comprises plastics (Heap, 2009; Naidoo *et al.*, 2015). Plastics are transported to the marine ecosystem by wind, flash floods, urban drainages and rivers, currently impacting life forms (aquatic and bird species) in a number of ways. Plastics cause entanglement, gut impaction, transfer of toxic organic chemicals, and changes of habitats among others in the African oceans (Vegter *et al.*, 2014). Specifically, exposures to degraded plastics particles (the microplastics) confers toxic endocrine disrupting effects of phthalates and Bisphenol-A, which are normal compounds used the manufacture of the plastics (Talsness *et al.*, 2009).

4.2.2.6.3. Air Pollution

Important chemical pollutants emitted from the various anthropogenic activities include oxides of sulphur (Sulphur oxide, Sulphur dioxide, and sulphate), noxious nitrogen gas (Nitrogen monoxide, Nitrous oxide, Nitrogen dioxide) ammonia (NH_3), volatile organic compounds, and carbon monoxide (CO). The effects of these on ecosystems is growing with the growth of the related anthropogenic activities i.e., urbanisation and industrialisation. The African urban centres have grown tremendously in the last thirty years, a trend that is on a continuous rise (Obeng-Odoom, 2013). The internal combustion engines of motor vehicles, power generation plants and other industrial machinery notoriously produce toxic gases, Nitrous oxide, Sulphur oxide and carbon monoxide. The propensity for formation of tropospheric (bad) ozone from the precursor Nitrous oxide are greatly enhanced in presence of Ultraviolet radiation. Thus, comparable pollution in the tropics may exact more adverse effects on sensitive species of diverse plants and animals than in the better studied temperate regions where it has been observed that photochemicals have resulted in shifts of vegetation from ozone sensitive to ozone tolerant ones (Barker *et al.*, 2012). Sulphur dioxide and hydrogen sulphide emitted from power plants especially the coal fired ones and paper and mill factories have already resulted to acid rains in various parts of Africa (Europe *et al.*, 2006; Nduka *et al.*, 2008; Josipovic *et al.*, 2010). The most relevant sources of NH_3 in Africa are municipal effluent, farmyard/feedlot manure, and inorganic mineral fertilizers (Carmichael *et al.*, 2003). The extent of production of dioxin from incineration of municipal waste, a common practice in Africa, has not been evaluated. However, given the rise in the quantities of wastes, this is expected to contribute to air pollution in many parts of the continent. Particulate matter (PM- the most health-damaging components characterized as PM2.5) is generated by a combination of anthropogenic and natural courses. According to the latest air quality database from World Bank, particulate matter levels in most parts of Africa are decreasing (Figure 4.17).

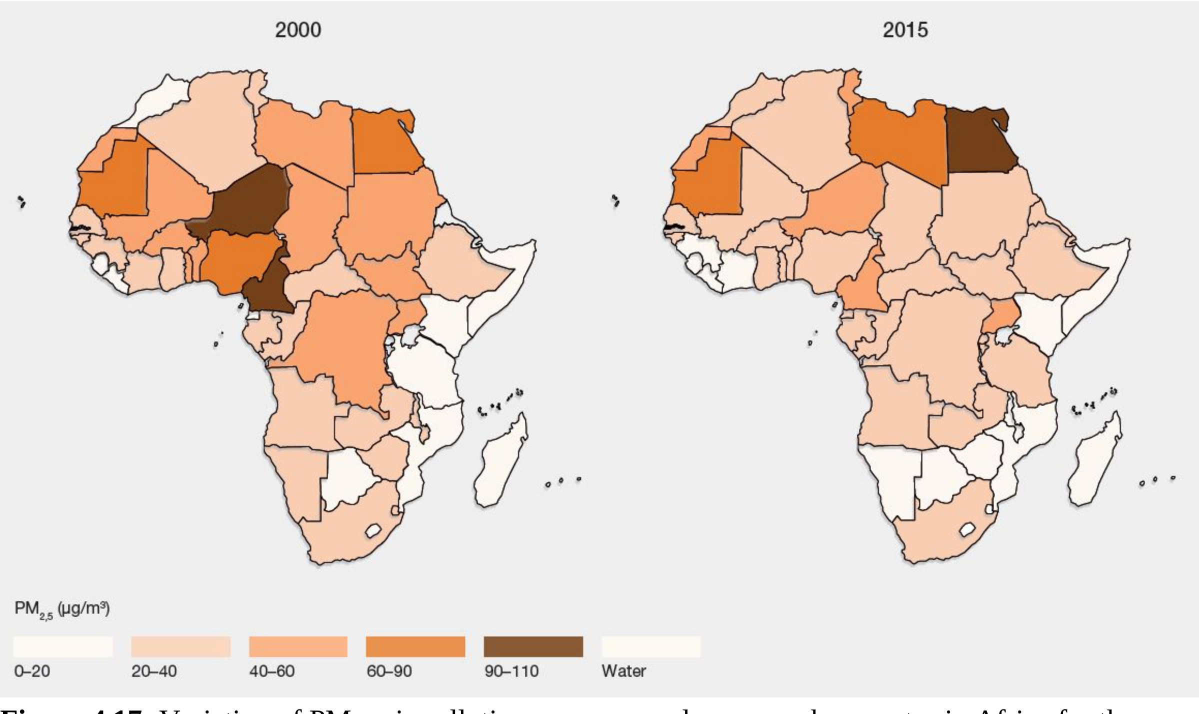


Figure 4.17: Variation of $PM_{2.5}$ air pollution, mean annual exposure by country in Africa for the years 2000 and 2015. The darker the shade, the higher the value. Source: World Development Indicators (2017).

The rate of urbanisation supersedes the rate of development in many of the poorer African nations. The long distances of unpaved dirt road in addition to deforested bear grounds in heavily settled area are important sources of dust in many parts of Africa. Various mining activities in Africa contribute too much of the PM2.5 in the atmosphere and studies reveal detrimental effects on biodiversity (Munnik, 2010; Ana, 2011; Gathuru, 2012). Africa is also faces a number of natural sources of air pollutants including Sulphur oxide, Nitrous oxide and dust. These arise from eruption of active volcanic mountains; emissions from hot springs in the eastern rift valley from Ethiopia through Kenya and northern Tanzania; dust from the Saharan desert, pan surfaces, and ephemeral lakes in South-Western Africa; methane emission by the termites; and methanogenic bacteria in the swamps. In particular, the continual expansion of the Sahara has led to four-fold increase of dust (Prospero *et al.*, 1986; Bryant, 2003), which is mostly disturbed and therefore laden with Iron. Iron-laden dust has been observed to deposit in the Equatorial Atlantic and could enhance nitrogen fixation and consequently exacerbate occurrence dead zones at ocean (Tegen *et al.*, 1995). The physical anthropogenic pollutants like noise, light, and radioactive materials, are also known to hamper biodiversity in various ways.

4.3. Link between natural and anthropogenic drivers

There is interplay between multiple drivers of biodiversity and ecosystem services (Figure 4.18). Most direct anthropogenic drivers are a consequence of interaction between indirect drivers and natural drivers. It is often the direct interaction of humans with the natural environment that causes land conversion from natural systems to agriculture, or degradation of the natural or agricultural systems. However, factors that determine how humans interact with the environment are extremely complex. There is an interplay between the natural features of the land, institutional factors and economic factors. Features such as soil characteristics, climate and terrain determine the likelihood of degradation under different land-use interventions. Institutional factors set the ‘rules of the game’ and these are determined by cultural and traditional values, local and national institutional structures, religious beliefs, policy and legislation. These institutional aspects define how things are done in the society. Finally, economic aspects determine the demand for produce, which will impact on how the land is used. This demand may be local for subsistence needs, but is increasingly global in nature (Hubacek *et al.*, 2002).

4.3.1. Link between anthropogenic and local drivers

At the local level a growing human population creates an increased demand for agricultural and other natural products. In Africa this translates mostly into an increased area under agriculture, rather than agricultural intensification, though there is a growing trend towards intensification (Perring *et al.*, 2015). The link between resource degradation and society is complex, but it is widely accepted that degradation both causes and results from socio-economic conditions such as poverty (Reynolds, 2007). Although poverty and increased population have been linked to resource degradation (Malthus, 1798; UNFPA, 2001; de Sherbinin *et al.*, 2008), this causation is contentious (Malik, 1999; Geist *et al.*, 2001; Bremner, 2010), with recent studies suggesting that in many cases it is global consumption patterns that have far greater impacts on degradation than the poor (Current *et al.*, 2004; Dietz *et al.*, 2007; Bremner *et al.*, 2010). However, there are cases where increasing population can lead directly to increased pressure on the land and increased degradation (Coppock, 2016). But, population does not always lead to increased degradation (Tiffen, 1994). In many cases it is the strength of local institutions that allow sustainable management of communal resources (Ostrom, 1990), but in the Machakos example, changes in policy (particularly relating to tenure), technical and political support all played a part (Tiffen, 1994). Africa has embarked on a wide range of projects involving devolution of natural resource management to local communities in the forestry and wildlife sectors in response to renewed understanding of the importance of local institutions in resource management (Shackleton *et al.*, 2001; Roe, 2009; Chevallier *et al.*, 2016).

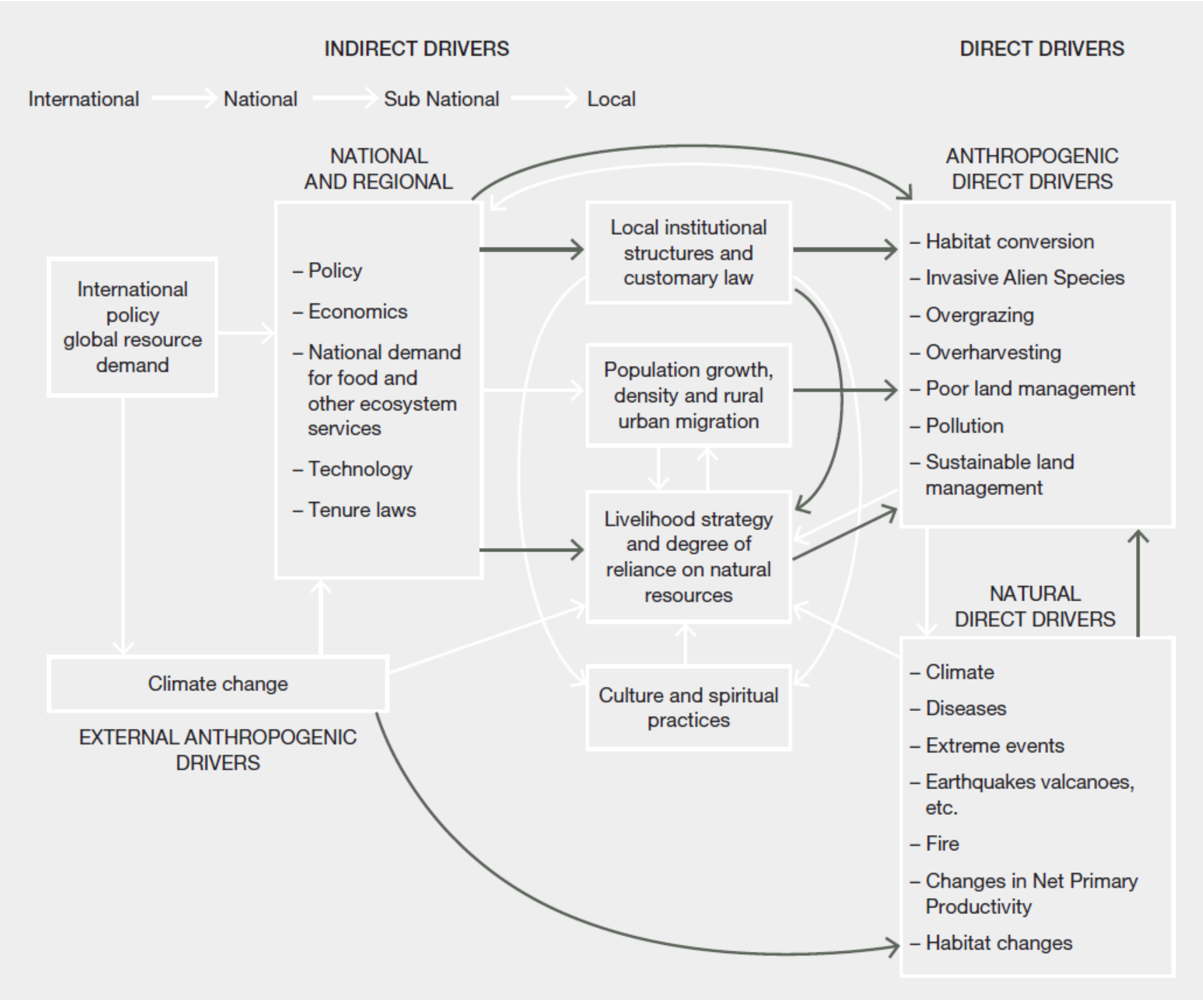


Figure 4.18: A schematic representation of the complex interactions among drivers. Indirect and natural drivers impact local individuals and communities through complex chains leading to direct anthropogenic drivers.

Poverty tends to force people to have greater reliance on the environment and this can lead to degradation as the meeting of short-term survival needs may be more important than long-term sustainability. This is especially true during times of stress such as during a drought. Though poverty is often associated with degradation, a lack of poverty (wealth) is no guarantee that degradation will not take place, especially if policy gaps, or perverse policy outcomes, allow inappropriate land management practices. Despite this, in most respects the poor have a far smaller environmental footprint than the rich (Fischer-Kowalski *et al.*, 2011; Ivanova *et al.*, 2015; Kenner, 2015). Large-scale migration to towns, and increased urban affluence, place a high demand on rural areas to increase food production. The increasing extent of urban poor, living in slum areas associated with Africa's large cities place unique threats to the environment through their requirements for cheap food and fuel, as well as the local impacts (Satterthwaite *et al.*, 2010). The need for cash in an increasingly cash-based economy is changing resource use from traditional consumption to marketing. There is probably no community left in Africa who does not require some level of cash income. This can drives new behaviour which will differ from the traditional livelihood resource use patterns such as charcoal production and the sale of bushmeat to urban centres (Bennett *et al.*, 2007; Zulu, 2010; Bolognesi *et al.*, 2015; Neufeldt *et al.*, 2015).

Traditional, religions and cultural structures, local indigenous knowledge, ability to access technologies, poverty and access to land have a powerful impact on local level land-use practices. Care for, and understanding of, their environment is a strong driver of resource use, some of this deeply embedded in traditional knowledge and belief systems. Many local institutional structures have been weakened through centralized governance in colonial and post-colonial government systems (Chevallier *et al*., 2016). These are determined by tradition, access to capital, access to markets, availability of technology, and inherent productive capacity of the area, tenure regimes any many other factors. Traditional structures should not be over romanticized, as although they often promote sound resource management, there are also cases of greed and rent-seeking behaviour by the local elite (Chiweshe, 2016; O'Laughlin, 2016). Households may well be forced to overexploit resources due to poverty, especially during drought years. Reduced size of farms due to population expansion may force households to undertake destructive activities such as overgrazing or unsustainable harvesting of fuelwood products. As there is a global shift to a cash-based economy, households are under increased pressure to find economic opportunities from the land.

4.3.2. Link between anthropogenic and national and regional drivers

National rules and regulations define how people can legally use the land (Chevallier *et al*., 2016). This therefore constitutes one of the biggest single drivers of land-use activity. However, it is the state's ability to police these rules and regulations that will determine if they are adhered to at the local level. Many land-use practices such as charcoal production or harvesting of wild animals are illegal, but due to inadequate enforcement, are still widespread (Bennett *et al.*, 2007; Zulu, 2010; Bolognesi *et al*., 2015; Neufeldt *et al*., 2015). In addition well-intended legislation in one sector of the economy might provide perverse incentives for resource destruction in other sectors of the economy (Zulu, 2010). Macroeconomic policy has far-reaching impacts as to how communities engage with resources. Macroeconomic and political aspects of the economy often drive the status of local development. Taxes and economic incentives are the two key instruments available from an economic perspective to govern land-use activities. This determines options available to local residents in terms of the types of practices they can undertake. For instance there is ongoing debate over large-scale foreign direct investments in land versus small-scale farming (Cotula *et al.*, 2009; Vermeulen *et al.*, 2010; Hall, 2011; von Maltitz *et al.*, 2011).

4.3.3. Link between anthropogenic and global drivers

Increased global demand of ecological services such as tourism increases pressure on ecosystems. Africa is affected by both import and export policy, with cheap food imports often having negative feedback into the agricultural economies. Exports drive new agricultural practices and crop choices. Global trade on commodities dependent on natural resource such as cash crops (e.g., horticulture in Kenya and Ethiopia) and beef (cattle production in Botswana and Namibia for the European Union market) has been shown to contribute to degradation of natural ecosystem and loss of biodiversity (Swanepoel *et al.*, 2010). The demand for beef is projected to increase by 115% between 2000 and 2050 globally (Alkemade *et al.*, 2013). This will require more grazing area, and rangelands will experience further degradation and biodiversity loss. In addition, use of local livestock breeds such as Tswana cattle in Botswana are often ignored in favour of heavy exotic breeds due to market demand and this could facilitate loss of national biodiversity.

4.3.4. Link between anthropogenic and natural drivers

A number of studies suggest that it is during or after extreme events that degradation processes are initiated (Frank *et al.*, 2015). These could be from cyclic climates, or impacts from global climate change. For instance a prolonged drought could lead to heavy overgrazing, especially if artificial water points are provided, resulting in the removal of almost all ground cover. This would then make the area extremely vulnerable to erosion if there is an intense storm following the drought. Table 4.7 attempts to map how different natural degradation drivers might impact with direct anthropogenic drivers.

4.3.5. Link between anthropogenic drivers and climate change

Climate change is a unique anthropogenic driver of change that its impact is spatially decoupled from the source, and in that at the local scale, communities can only adapt to impacts, but cannot change the scale of the impacts through their local actions (Harrison *et al.*, 2016). There are a number of complex interactions between climate change and the natural environment, potentially decreasing the ability of the natural environment to sustain the same level of the provisioning on nature's contributions to people. The impact is likely to be most severe in drylands (Huang *et al.*, 2017) and the combined increase in temperature, decrease in rainfall and change in seasonality will prove exceptionally problematic to livestock production (Descheemaeker *et al.*, 2017).

Climate change may radically alter species composition and distribution in the natural environment, and in so doing change the available mix of nature's contributions to people that is available to support livelihoods. This may have dramatic changes on livelihood strategies including farming practices. Climate change may well alter the distribution and likelihood of many diseases. It is also expected to alter natural fire regimes, potentially increasing the possibility of mega-fires, which have devastating human and environmental impacts. With regards to invasive alien species, evidence suggests that Water fern (*Azola filiculoides*), Water hyacinth (*Eichhornia crassipes*) and the Kariba weed (*Salvinia molesta*) will expand towards suitable habitat found in the Western Cape Province and along coastal areas in South Africa (Hoveka *et al.*, 2016). The rate and extent of this spread will depend on local climate, vegetation and disturbance contexts (Clements *et al.*, 2011).

Table 4.7: Enhancement of natural drivers by anthropogenic drivers of change.

	Natural climate and weather patterns	**Extreme events (droughts, cyclones, floods)**	**Wildfires**	**Diseases**	**Earthquakes, tsunamis, eruptions**
Habitat conversion	Erosion and runoff for bared soils	Can enhance floods	Deforestation facilitates wildfires–wildfires maintain deforestation	Loss of marshes can reduce disease risks (malaria)	Could destroy natural habitats
Resource overutilization	Erosion and runoff for bared soils	Can enhance droughts effects through depleting plant cover–often high reliance of natural products due to	Deforestation facilitates wildfires, which facilitate biomass depletion Human-induced fires lead to wildfires (honey	Resource overutilization may affect health and facilitate diseases	(No effects)

		agriculture collapse	harvesting, promoting grazing)		
Management practices	Erosion and runoff for bared soils	Can enhance droughts effects through depleting plant cover	Bad pasture management can facilitate wildfires	Agro-ecological practices may enhance soil biological activity, then reduce crop diseases	(No effects)
Invasive alien species	Can decrease or increase erosion and runoff	Dispersal of invasive alien species on a larger range	Some invasive alien species plants can facilitate wildfires– increase fire intensity and destroy soil	Some invasive alien species are pathogens for human, cattle, crops	(No effects)
Pollution	Air pollution and water pollution may be exacerbate d by climate change	Extreme events can concentrate pollutions, and or move then into river systems	Smokes from wildfires enhance air pollution	Allergies caused by pollution	(No effects)
Climate change	More extreme droughts, more severe floods, greater chance of erosion, greater chance of invasion	More extreme more frequent greater severity (of droughts floods	More extreme, hotter fires More often (but depends on biomass accumulation) Possible biome shift to no fire.	Greater chance of disease range expansion	(No effects)

4.4. Indirect drivers of change

Africa’s development outcomes for the coming decades will be determined by a number of drivers of change, and the policy changes adopted by African countries in response to changing world conditions (AfDB, 2011). Cumulatively, these drivers are likely to create dramatic changes for the African continent and the global environment with which the continent interacts. Africa has some of the most abundant natural resources in the world, including its biodiversity. The continent’s development trajectories are projected to increase impacts on ecosystems. Economic growth, through production and consumption chains, human settlements and infrastructure development, will be a key driver of change. Many states in Africa have a vision to become emerging economies in the coming decades. This is compounded by rapid population growth and urbanisation, policy and cultural changes, and global resource demand especially for food, energy, water and other extractives. With increasing raw material extraction for economic growth and weak institutional arrangements, countries in Africa are experiencing unprecedented rate of resource exploitation in recent time (Ozor *et al.*, 2016). For example, increased exploitation and clearing of forests for timber and agriculture, though it has economic benefits, may result in loss of biodiversity and reduction of the potential of forests to provide nature's contributions to people (Hawthorne *et al.*, 2011; Roué *et al.*, 2016).

4.4.1. Policy Changes

4.4.1.1. Economic policies

Since the advent of independence for most African countries, the African continent has struggled with a seemingly endless array of development challenges which range from civil war and political instability to disease epidemics, chronic food insecurity and pervasive poverty (AfDB, 2011). Africa's prospects for economic development will largely depend on the policies it implements to take advantage of its vibrant young population, its abundance of natural resources and its considerable human capital. Ending all forms of poverty is the highest priority for Africa (AMCEN, 2015; AU, 2016) hence policies and strategies for national governments, regional communities and development partners are geared towards this goal (AU, 2016). This is exemplified by the planned $360 billion African Development Bank Programme for Infrastructure Development in Africa (PIDA) to address projected infrastructure needs by 2040 (AfDB, 2010). The risk on biodiversity and ecosystem services, associated with major infrastructural development such as the Grand Inga Dam in DR Congo or the Lamu Port South Sudan Ethiopia Transport corridor in Kenya, are immense. In a bid to chart a way to sustainable development, a number of countries in Africa (e.g., Kenya, Mozambique, Rwanda, South Africa, Tunisia, Republic of Congo, etc.) are developing green economy policies to guide sound management of natural resources and their sustainable use.

4.4.1.2. Environmental policies

Although the future is shrouded in uncertainty, some of the parameters that will determine Africa's future in biodiversity conservation are visible today. What is required is a clear-sighted analysis to identify the challenges and opportunities that lie ahead. This is because biodiversity conservation is mainly implemented through management of protected areas policy (Iritie, 2015).

Weak or inadequate policies in the conservation of biodiversity and ecosystem services have resulted in local extinctions or reduction in the diversity and richness of some species. A lack of harmony in national policies across regions has resulted in incoherent and sometimes unregulated exploitation of species such as elephants and lions. Formulation of appropriate policies at regional level, or harmonization of existing ones to ensure coordinated approach is likely to lead to effective conservation of biodiversity and transboundary ecosystems. A good example is the 520,000 km^2 Kavango Zambezi (KAZA) Transfrontier Conservation Area (TFCA) in the Okavango and Zambezi river basins at the convergence of Angola, Botswana, Namibia, Zambia and Zimbabwe borders. KAZA-TFCA provides safe corridors for wildlife movement between its 36 national parks, game reserves, community conservancies and game management areas. Recognising biodiversity and ecosystems as natural capital would enhance value to functions and services they provide. This would require that countries undertake valuation of their natural capital. That economic value of many protected area systems has not been undertaken and this may lead to the view that they contribute minimally or have no value for a country's economic development.

4.4.2. Governance systems

Governance is a timeless phenomenon that humans experience in their interaction with people and nature. In the present human can alter the conditions of the entire planet by through innumerable acts of decision-making that affect nature or, in a more institutional sense, innumerable acts of exercising power, authority and responsibility with direct relevance to nature (Crutzen, 2006). Governance has thus to do with policy (stated intentions backed up by authority) and with practice (the direct acts of humans affecting nature). In between, it has to do with the complex web of conditions understanding, communicating, and allocating power and resources–which create matches and mismatches between the two.

Governance for the conservation of nature seeks a balance between the requirements of human and economic development and those of conserving biological diversity. The key major international policy expressions are the Sustainable Development Goals, the Convention on Biological Diversity and the UN Framework Convention on Climate Change. Attention should also be focused at the national and local levels, and on area-based measures in particular. In reality, the policy and practice of conservation have always been enmeshed with the struggles for 'power over nature' that have unfolded throughout history. Considerations of governance–that is, who holds de facto power, authority and responsibility to take and implement decisions - are crucial for biodiversity conservation. In the distant past, the interaction between people and the environment were more likely shaped by patterns of necessity and adaptation than by 'decisions'. For example hunter-gathering lifestyle in many parts of Africa allowed livelihoods to be sustained with limited disturbance of the ecosystem functions.

Through time, landscapes and seascapes were identified as 'units', or territories of different people, often on the basis of different perceived vocations and patterns of interactions between people and nature. With the increased complexity of societies, expanded communication and trade, enhanced knowledge of the environment and enhanced technology to exploit its riches, both such interactions and units have changed, sometimes dramatically through decisions taken by relevant people and authorities. Similarly, the units (a village territory, a country, an administrative region, and the property of a given family) are increasingly more politically determined than determined on the basis of the intrinsic properties of the ecosystems.

Previous generations of people on the African continent had much less access than many of us to stored information, but an amazing capacity to learn and accumulate observations and experiences, in particular regarding specific places. Through time, acting and receiving feedback from nature consolidated into bodies of local knowledge and skills, varieties of carefully selected seeds and breeds, and allocation of different uses to different units in the landscapes and seascapes, based on deep knowledge and understanding of their potential. Many indigenous peoples and local communities continue to govern and manage their landscapes drawing from these accumulated observations and experiences. Throughout history, however, humans not only perceived and adapted to their ecosystems, they also affected them in important ways (Goudie, 1990). This began with the use of fire, the movement of seeds by hunter-gatherers and the changes to soil and waters made by agriculturalists (Goudie, 1990). Our landscapes and seascapes are delineated into administrative units where decisions about such units have mostly to do with how they will to be utilized for socio-economic developed and how much importance is given to considerations of sustainability and the conservation of ecological and cultural values. In other words: are the pressures of urbanisation, trade, infrastructure, industry, agriculture, aquaculture, mining, logging or large-scale tourism going to be reined in? Do decision-makers uphold the local ecological and cultural values by declaring that at least a given area is 'protected', that a watershed should not be altered, or that a given species is endangered and must be cared for? The compromises struck by policymakers about these questions are at the heart of today's governance of the conservation of biodiversity. And, in many such situations, the fundamental decision is about breaking the landscape or seascape into governance sub-units—some dedicated to development and others to conservation—generally under different governing bodies.

A country's governance systems have a direct impact on biodiversity conservation. Yet the state is no longer the sole actor responsible for managing environmental externalities (Agrawal *et al.*, 2007). Participatory management policy guidance, conveyed in connection with the IUCN (Dudley, 2008), has shown their limits in Central Africa (Joiris *et al.*, 2014). Hence the need for contextualized sustainable management systems. Ratification and mainstreaming of International multilateral environmental agreements in national policies will be key to making significant contributions to the sustainable management and use of biodiversity. For instance, the Convention on Biological Diversity's Article 6 is an unqualified commitment requiring Member States to develop a national biodiversity strategy and action plan (NBSAP) (or an equivalent instrument), and to integrate conservation and sustainable use of biodiversity into sectoral and cross-sectoral activities. NBSAPs therefore provide an opportunity to address threats to biodiversity through policy integration in a country's development agenda.

The Convention on Biological Diversity and the Sustainable Development Goals embrace the three principles of inclusion, equity and justice which resonate with Africa. Equity has three dimensions, which create an enabling environment for effective biodiversity conservation; recognition, procedure and distribution (Box 4.9).

Box 4.9: Principles of inclusion, equity and justice, as embraced by CBD and the SDGs
(Source: Convention on Biological Diversity Capacity-Building Workshop for Africa on Achieving Aichi Biodiversity Targets 11 and 12, 21 -24 March 2016, Entebbe, Uganda)

Recognition

Recognition and respect for human rights.
Recognition and respect for statutory and customary property rights.
Recognition and respect for the right of indigenous peoples to self-determination.
Recognition of different identities, values, knowledge systems and institutions.
Recognition of all relevant actors and their diverse interests, capacities and powers to influence.
Non-discrimination by age, ethnicity, language, gender, class or beliefs.

Procedure

Full and effective participation of recognised actors in decision-making.
Clearly defined and agreed responsibilities of actors.
Accountability for actions and inactions.
Access to justice, including an effective dispute-resolution process.
Transparency supported by timely access to relevant information in appropriate forms.
Build on rights-holders' customary governance and management arrangements
Identification and assessment of costs, benefits and risks, and their distribution and trade-offs.

Distribution

Effective mitigation of any costs to Indigenous Peoples and local communities.
Benefits shared among relevant actors according to one or more of the following criteria: equally between relevant actors or according to contribution to biodiversity conservation, costs incurred, recognised rights, or the needs of the poorest.
Benefits to the current generation do not compromise benefits to future generations.

Some African states are promoting the implementation of articles 8 and 10 (c) of the Convention on Biological Diversity, the Nagoya Protocol and the United Nations Declaration on the Rights of Indigenous People in order to preserve and maintain knowledge, innovations, technologies and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and encourage the equitable sharing of the benefits arising from the utilisation of such knowledge innovations and practices (Lewis, 2010; AU, 2013).

4.4.3. Economic systems

Economic activity involves process that combines physical inputs and human efforts to produce goods and services for the improvement of human well-being. A wide range of economic factors influence how human use and impact on biodiversity and ecosystem services. Some of these include macroeconomic development pathways and fiscal regimes. Macroeconomic development discourses, policies and strategies on the continent have long been based on maximising African nation's economic growth and development, with limited change in the structure of Africa counties' economies over the past five decades (AfDB *et al.*, 2015). Economic activity and growth are influenced by the dispensation of natural resources, including ecosystem services (natural capital), the number and skills of humans (human capital), market reach (trade), institutional and policy environment and more strongly by available technologies. In Africa primary activities based on the exploitation or extraction of natural resources (i.e., biomass; fossil fuels - coal, oil and gas; metal ores and non-metallic minerals) continue to dominate (Collier, 2002). With Africa's economic growth of 3.6% in 2015 (AfDB *et al.*, 2016) and expected 5% in 2016 (AfDB *et al.*, 2015), there is no evidence of decoupling between biodiversity loss and current development pathways based on increasing demands for ecosystem services accompanied by large-scale habitat transformation.

The rich resource base in many African countries has been a major driver and engine of economic growth in the region. Foreign exchange earnings from resource exports enabled African countries to import important intermediate inputs and also finance some national development programmes. In as much as African countries benefited from their resource endowments, some of these resources are non-renewable. Their rapid depletion by the current generation will limit their capacity to meet the consumption needs of the future generations, especially if there is no investments in assets that support future growth, (UNCTAD, 2012). Most developing countries have in the last three decades transitioned considerably in the latest wave of globalisation from primary export commodities to manufactures (Collier *et al.*, 2002). However, Africa has not broken into the global market for manufactures and remains heavily dependent on primary commodities (Collier, 2002). This places increasing high demand for natural resources by emerging and developed economies. Pressure on the African biodiversity and ecosystems has been immense and persistent, (Nelson *et al.*, 2005).

Economic growth requires development and improvement of physical and institutional infrastructure to facilitate transportation, marketing, settlements, public services, and private-sector activities (Nelson *et al.*, 2005). Further the proposed development corridors would involve largescale expansion of infrastructure resulting in increased pressure on the environment and biodiversity (Laurance *et al.*, 2015). The development of planned infrastructure will play a major role impacting on ecosystems. Infrastructure development is an important direct driver of biodiversity change (Figure 4.19).

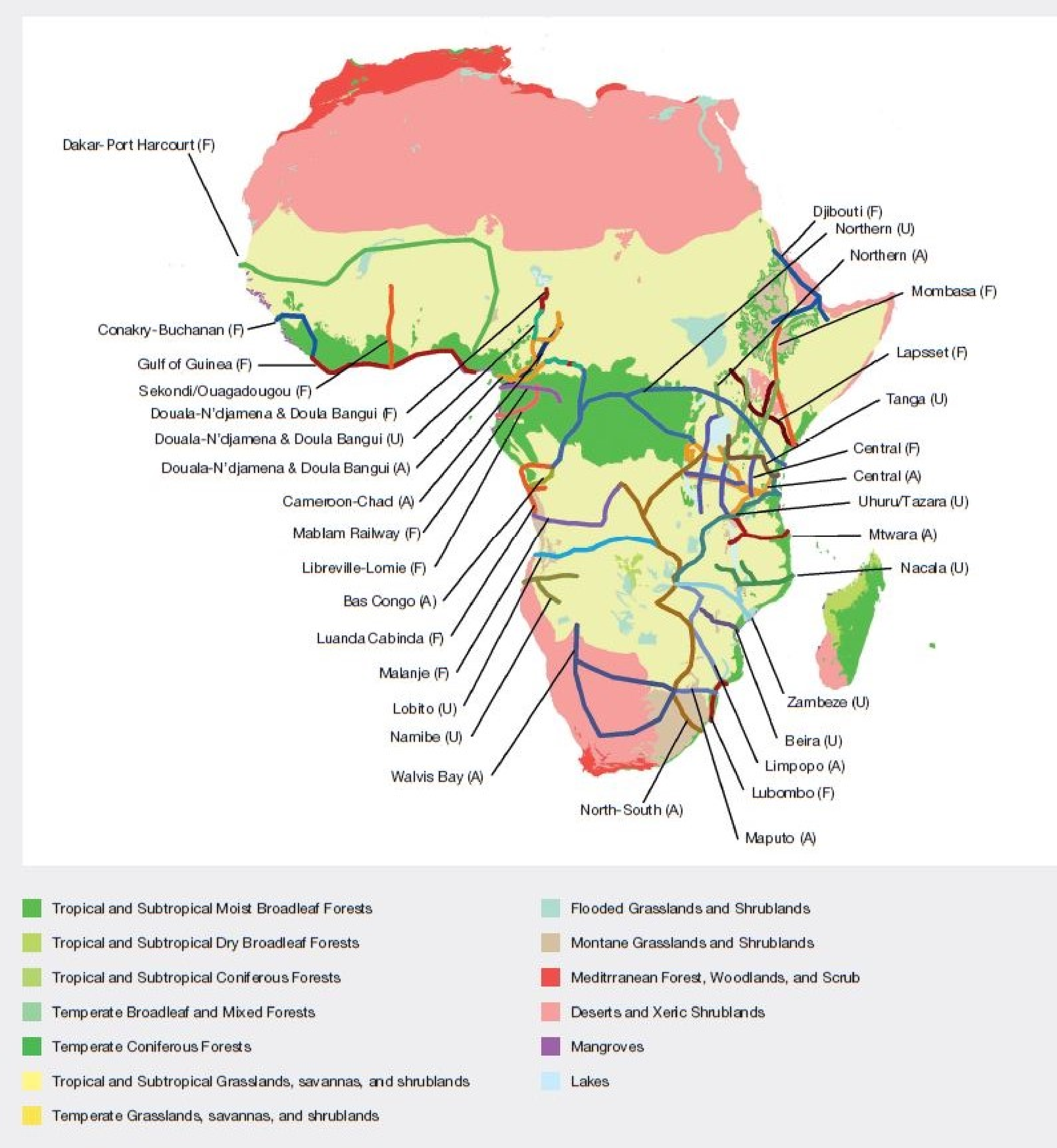


Figure 4.19: Map of future development corridors and likely scenarios of development pressure on African ecosystems. Legend: A = already active; F = planned for the future; U = upgrade planned or underway. Source: Laurance *et al.*, (2015).

Joint research by WWF and AfDB identified the Ecological Footprint of all African countries as increasing by 240% between 1961 and 2008. Africa was projected to be in a "biocapacity deficit" by 2015, i.e., the demand for resources and ecological services is now greater than the capacity of Africa's ecosystems to produce such useful biological materials and absorb waste flows generated by its populations (AfDB, 2015). This is particularly worrying given the growing reliance of African economies on the exploitation of renewable natural capital (AfDB, 2015). While the basis for the continent's development is increasingly broad, extractive sectors still act as a major source of export earnings and account for a significant share of Gross Domestic Product and its growth in many countries across the continent (AfDB, 2015).

Africa's primary commodities dependence has been attributed to a poor investment climate that is policy-related and handicaps manufacturing and agricultural processing that are intensive in transactions are considered a feasible means of lowering these costs in a coordinated way in order to enable the continent reach competitiveness in manufacturing (Collier, 2002). In addition, the African Union has promoted intra-African trade, by developing a trade action plans, i.e., Action Plan for Accelerated Industrial Development of Africa and Program for Infrastructure Development in Africa. However, the subsequent infrastructural development has improved trade but had negative impacts on the biodiversity and ecosystems functions and services.

To counter this, there has been a widespread development green economic strategies and policies in Africa to enable sustainable development in the region. A typical definition is that "green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies" (OECD, 2011). Green growth must be compatible with poverty alleviation strategies that address ecological scarcity, a major contributing factor to the vulnerability of rural economies. Green growth has focused on renewable technologies and climate change adaptation strategies such as reducing the emission of greenhouse gases, (OECD, 2011). Green growth has focused on renewable technologies and climate change adaptation strategies. Green economy policies have been developed with incorporation of biodiversity conservation. However, the concept of Public-Private Partnerships will require caution to ensure private companies engage fairly with local communities under the Prior Informed Consent principle. Hence, tackling the structural problem of the geographical clustering of impoverished households in marginal and remote areas with poorly integrated and functioning markets should be a focus for development policies that address changes in biodiversity and ecosystem services.

According to the United Nations Conference on Trade and Development (UNCTAD) report of 2012, the total domestic material extraction (i.e., biomass; fossil fuels - coal, oil and gas; metal ores and non-metallic minerals) increased from 2.8 billion tons in 1980 to 5.3 billion tons in 2008 in Africa, representing an approximate increase of 87% (Figure 4.20). This increase is in line with global trends although Africa's share in global extraction increased only marginally (UNCTAD, 2012). Biomass (e.g., agriculture, forestry, and fishing) is the most dominant material type extracted in Africa, accounting for 30% of overall material extraction in 2008. It increased from 1.7 billion tons in 1980 to 2.8 billion tons in 2008. Animal feed, particularly grazing activities (livestock breeding accounts for a high share in total land-use in many African countries), accounted for 58% of biomass extraction in 2008.

While the share of biomass in domestic extraction varies across African countries, it is important to note that non-renewable resources are increasingly playing an important role in several African countries. The average domestic material extraction per capita between 1980 and 2008 fell from 5.9 to 5.4 tons despite the global average increasing from 8.6 to 10.2 tons (Figure 4.21). During this period, high population growth resulted in the per capita domestic material extraction stagnation.

It is clear that there has been an increase in Africa's global market shares in exports of biomass due to higher increases in trade in other world regions. The transition from an agrarian to an industrial regime results in increased environmental pressures. Consequences range from climate change, waste pollution, deforestation, desertification and degradation of freshwater resources, to the loss of biodiversity (UNCTAD, 2012).

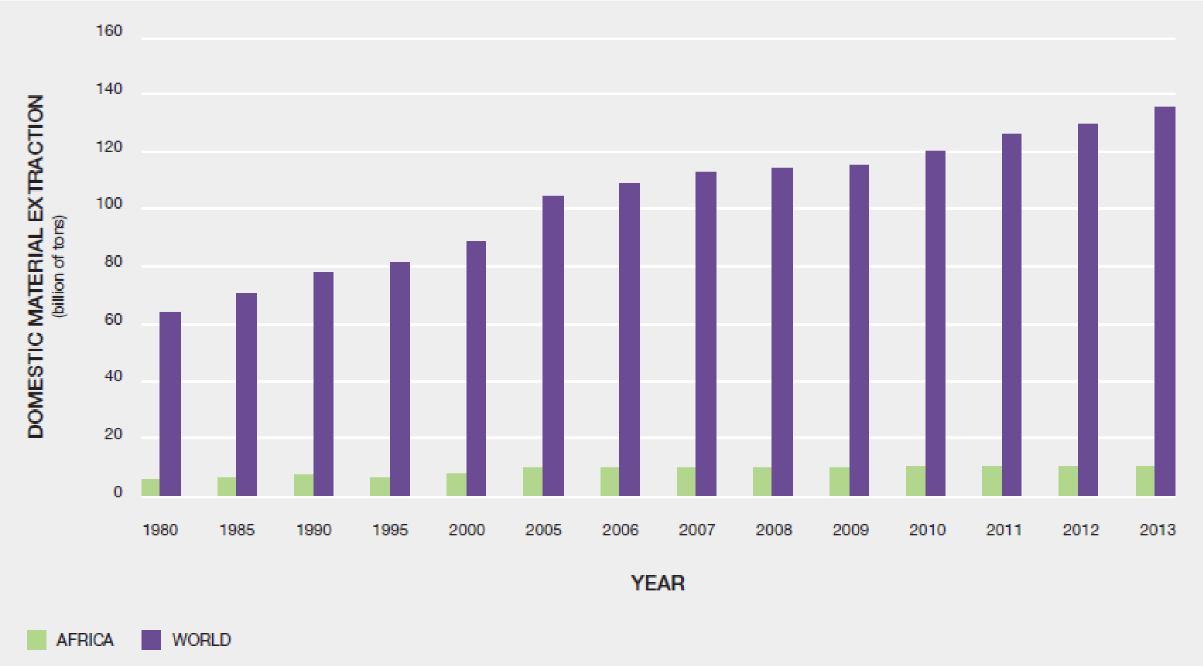


Figure 4.20: Global and African domestic material extraction (billions of tons). Data source: http://www.materialflows.net/materialflowsnet/home/

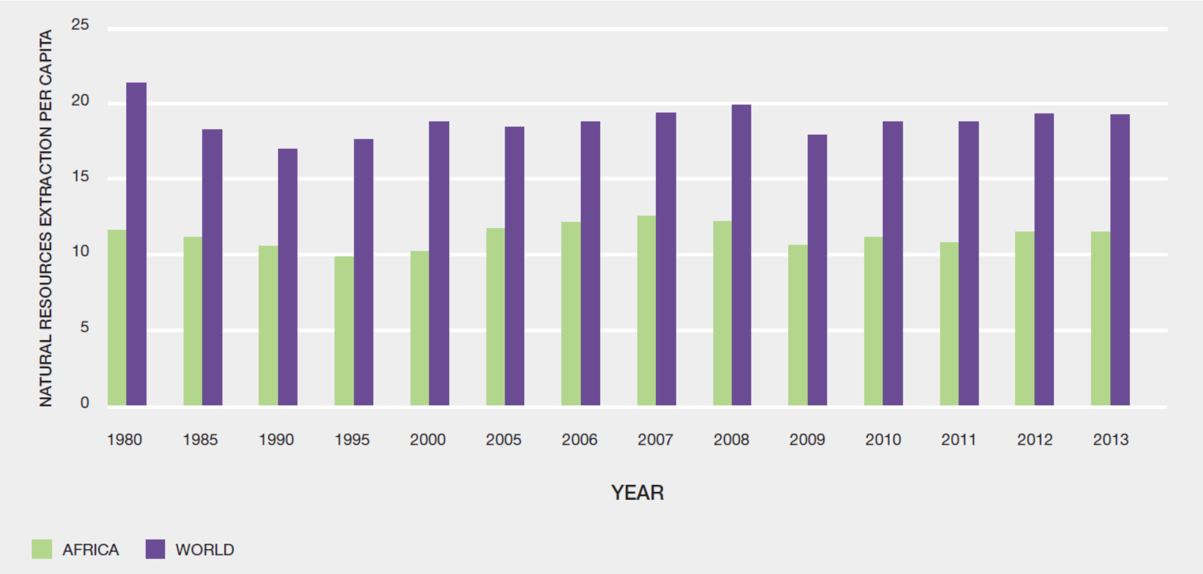


Figure 4.21: Natural resources (material) extraction per capita: Africa regional average and world average for the period between 1980 and 2008. Data source: http://www.materialflows.net/materialflowsnet/home/

There is a growing consensus that growth alone will not be enough for the continent to fulfil its aspirations. Debates on sustainable development pathways in Africa see various policy options and alternatives put forward (AfDB *et al.*, 2015):

- Industrialisation proposed as the mainstay of the African structural transformation, by emulating past policies of developed and emerging economies for full integration into world trade;
- The services industry as the new pillar of structural transformation because jobs in services continue to expand (e.g., outsourcing, new information and communication technologies);

- Pushing for further natural resources production, investing natural resource revenues wisely and simultaneously developing industrial policies which could diversify economies;
- Prioritising agriculturally-based growth given the current share of agriculture in employment; and
- Green growth strategies, calling for dramatic changes in production and consumption modes.

While each option tends to prioritise one sector or approach, some key institutions (e.g., African Development Bank) are working towards improving the quality of Africa's growth by coupling inclusive growth (e.g., equality of treatment and opportunity, deep reductions in poverty and a correspondingly large increase in jobs) to green growth strategies (AfDB *et al.*, 2015). It is thus imperative that its economy becomes more diversified over the next two decades in order to sustain future export-driven growth. Africa Development Bank and the World bank have noted that economies that do not diversify from their fossil or limited resource dependency, and/or fail to give adequate attention to the ecological impacts of resource extraction, will face the challenge of stranded assets, increasingly competitive global markets, and degraded ecological and infrastructure systems in the future (AfDB *et al.*, 2015).

One may highlight the lack of practical fiscal regimes to finance the required shifts in behaviour towards pro-biodiversity development pathways. Indeed, current fiscal systems worldwide typically ignore environmental and social externalities and are focused on taxing (or exonerating from tax) capital and labour. Defined by the Organisation for Economic Co-operation and Development and World Bank as a 'range of taxation and pricing measures that can raise fiscal revenues while furthering environmental goals', environmental or green fiscal reform has been and is being implemented in different ways on the African continent (van Kerckhoven *et al.*, 2014). The pool of available tools includes environmental tax reform, the reform of environmentally harmful subsidies, (auctioning) permits to pollute or exploit a resource, charges, levies and fines for environmentally damaging activities, as well as the wider discourse on getting the prices right which incorporates positive incentives such as payments for ecosystem services.

4.4.3.1. African Economic Community

The African Economic Community is composed of multiple regional blocs also known as. These consist primarily of trade blocs with many overlapping memberships. Regional integration and trading blocs were created as a means to achieve sustained development and increase participation in the global economy (Ntara, 2016). Poverty levels in the blocs remain high suggesting low impact of the regional economic communities in enhancing socioeconomic development in partner states (Sako, 2006). Majority of the poor live in rural areas and depend directly or indirectly on terrestrial, inland waters and marine natural systems for income generation. Thus by not stemming poverty overexploitation of these resources has contributed to accelerated degradation impacting on biodiversity and nature's contributions to people.

4.4.4. Population growth, migration and urbanisation

The African population is projected to nearly double from around one billion in 2010 to almost two billion by 2040, and may well reach 3 billion by 2070 (UN, 2014; Boke-Olén *et al.*, 2017; Figure 4.22). Countries that have the highest population growth rate in sub-Saharan Africa include Zimbabwe (4.36%), South Sudan (4.12%), Malawi (3.3%), Niger (3.28%), Burundi (3.28%) and Uganda (3.24%) (World Atlas, 2016). This rapid population growth is impacting urbanisation, a driving force behind many socio-environmental issues (Heynen *et al.*, 2006). Human migration in Africa besides rural-urban trends is also caused by conflicts in the region, deprivation of communities to their rightful land due to private acquisitions and infrastructural development, leading to disruption of ecosystems. The adverse effect of global warming will also increase rural-to-urban migration thus putting more urban infrastructure at greater risk due to extreme weather events. Available evidence suggests that natural population growth in cities is more important than migration and displacement in explaining the role of humans in influencing environmental change on the African continent (Parnell *et al.*, 2011).

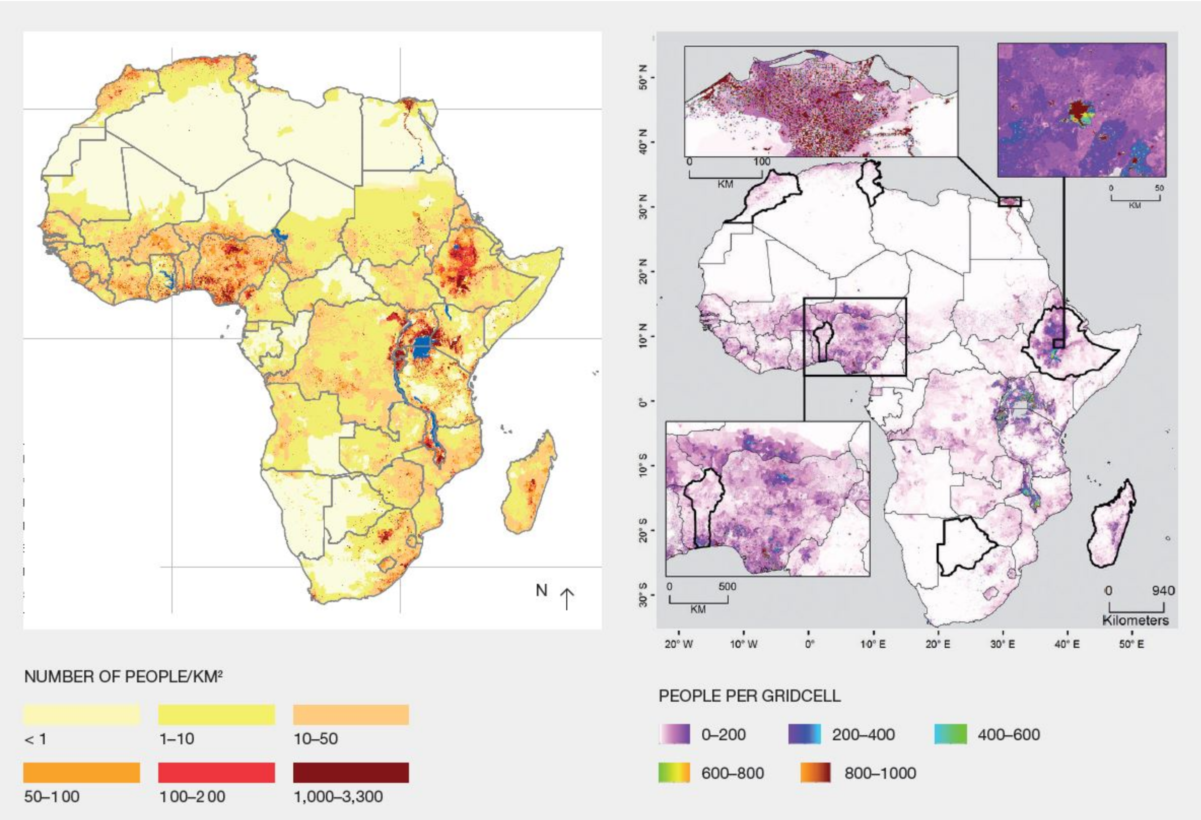


Figure 4.22: Population density in Africa in 2010 (left) and 2050 (right) (population datasets and SSP 2 and RCP 4.5). Source: Pesche *et al.* (2016); Boke-Olén *et al.* (2017).

4.4.4.1. Urbanisation trends

In 2003, 39% of Africa's 850 million people lived in urban settings and this is projected to rise to 54% by 2030 (Hay *et al.*, 2005). Overall, about half of the African population, i.e., 1.2 billion people, will live in a city by 2050 (Hay *et al.*, 2005). However, there are large variations in the patterns of urbanisation across African regions (Table 4.8).

Table 4.8: Urbanisation in African subregions: percent of populations in urban areas. Source: UN (2011).

Region	1950	1975	1995	2025
East Africa	5.5	12.3	19.4	44.7
Central Africa	14	27	34.2	61.5
Southern Africa	37.7	44.2	51.4	74
Western Africa	9.7	24.1	35.7	65.7
North Africa	25.8	39.3	47.2	65.3

North Africa has a higher proportion of urban population (47.8%) relative to sub-Saharan Africa (SSA) (32.8%) (Figures 4.23 & 4.24). Available data suggests that more than 50 million people in Africa will migrate to cities from rural areas with the cities growing twice as fast (by 100 million) just through natural in-city urban population growth. African cities will expand by 150 million people by 2020 (Parnell *et al.*, 2011).

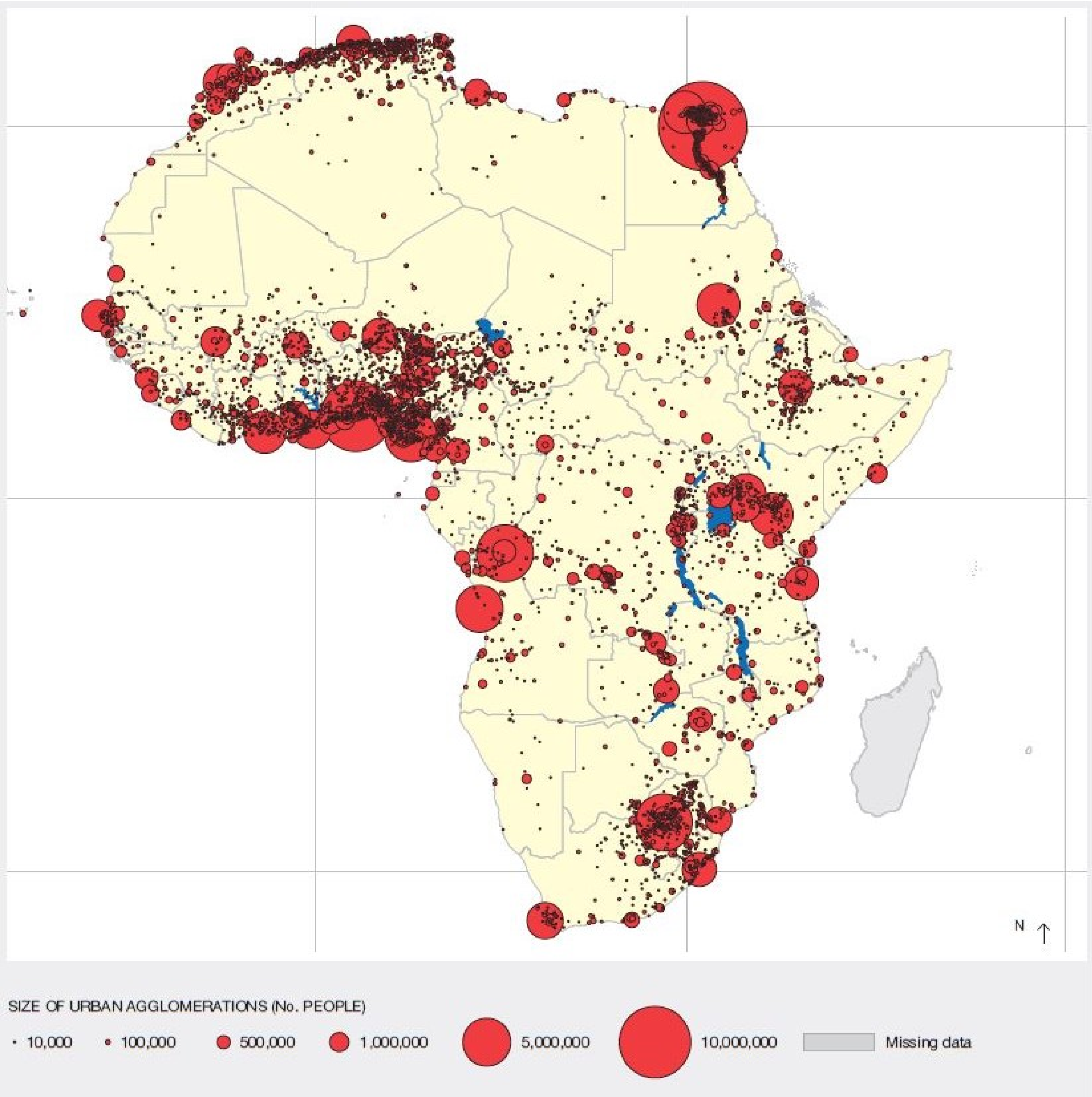


Figure 4.23: Urban population distribution across Africa (i.e., urban agglomerations of over 10,000 inhabitants). Source: Pesche *et al.* (2016).

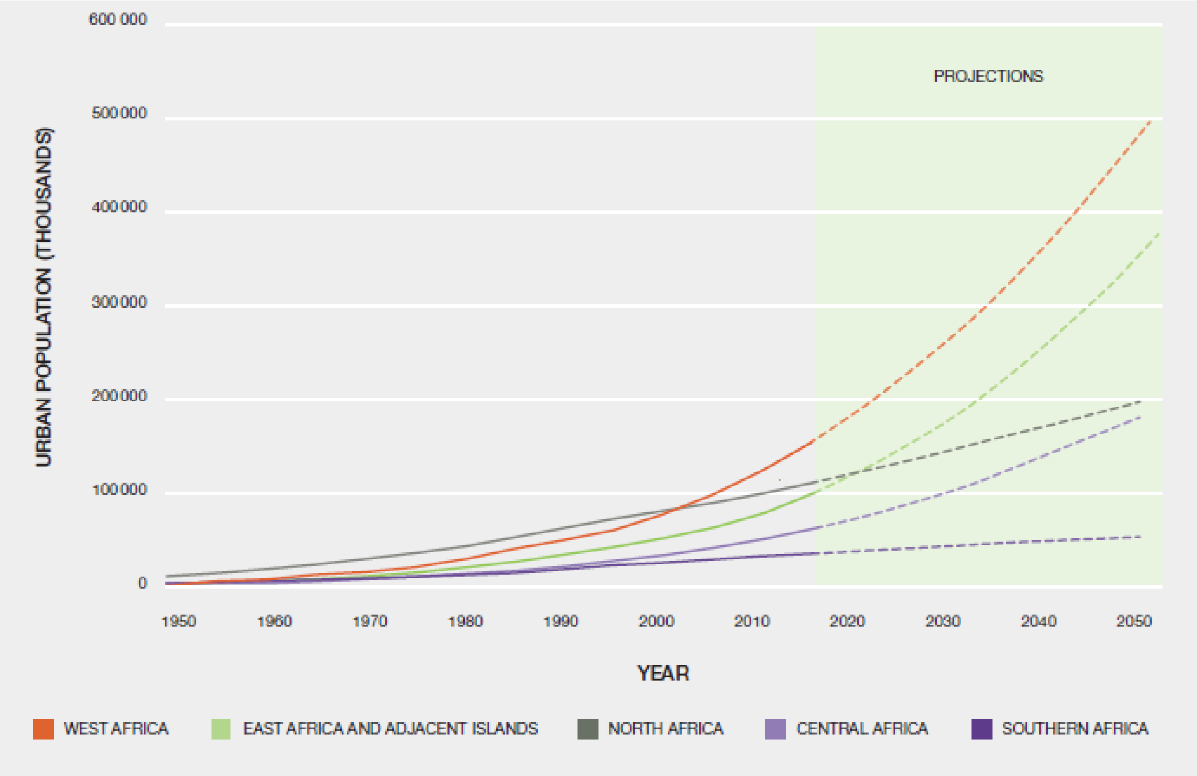


Figure 4.24: Rates of urban population growth for different African subregions. Note: South Africa and not southern Africa in this context. Data source: https://esa.un.org/unpd/wup/cd-rom/

Rural-urban migration (Figure 4.25), pro-urban development strategies, and high population growth rates are among the main causes of urbanisation in Africa. Searching for alternative livelihoods or economic opportunities mostly influences rural-urban migrants. There is therefore a great need for policies in the continent that encourage sustainable and equitable development by, for example, directing growth to areas where it can be sustained or redirecting urban expansion to more energy-efficient areas (IPCC, 2013).

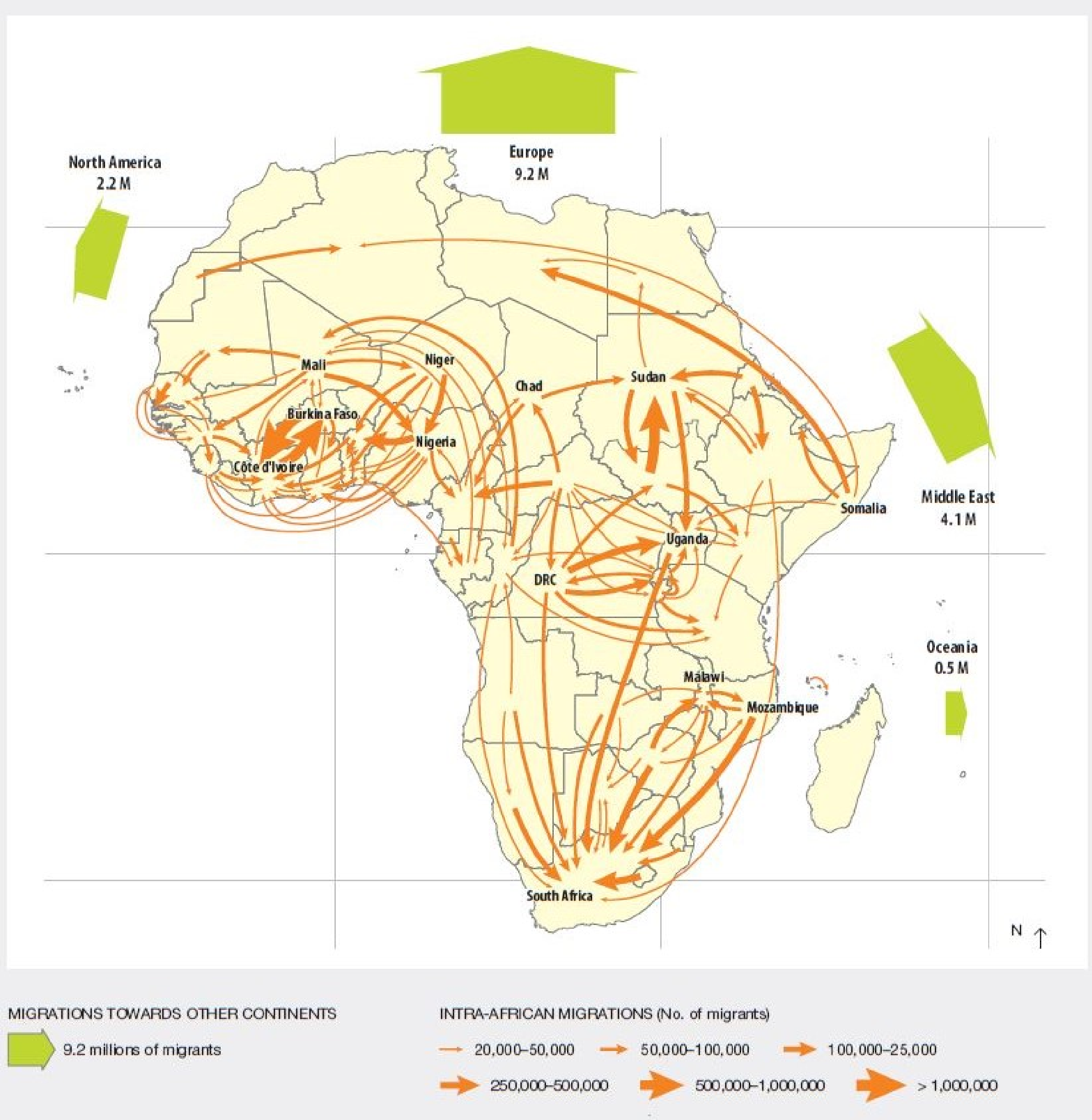


Figure 4.25: Population migration across Africa and from Africa to the rest of the world in 2015. Source: Pesche *et al.* (2016).

4.4.4.2. Environmental outcomes of urbanisation

Urban populations interact with their environment and change their environment through consumption of food, energy, water, and land. In turn, the polluted urban environment that is a function of consumption of resources and production of waste affects the health and quality of life of the urban population. Many of the effects of urban areas on the environment are not necessarily linear. Bigger urban areas do not always create more environmental problems. And small urban areas can cause large problems. Much of what determines the extent of the environmental impacts is how the urban populations behave–their consumption and living patterns–not just how large they are (Torrey, 2004). Further, development of infrastructure in urban areas enables them to cope better with the demands posed by the concentration of large numbers of people in limited spaces. Thus, wastewater works and drainage systems are critical to supporting urban populations and to mitigating the impacts of waste and pollution on the environment.

4.4.4.2.1. Land and wildlife habitats degradation

The pressure on ecosystem functions and services, particularly water and food (plant and animal based) causes an increase on the dependence on and demand for conversion of natural ecosystems into production landscapes, hence compromising biodiversity. Among the many human activities that cause habitat loss, urban development produces some of the greatest local extinction rates and frequently eliminates the large majority of native species (Marzluff, 2001). Also, urbanisation is often more lasting than other types of habitat loss. Throughout much of New England, for example, ecological succession is restoring forest habitat loss from farming and logging, whereas most urbanised areas in that region not only persist but continue to expand and threaten other local ecosystems (Stein *et al.*, 2000). In addition, most policies prioritize human settlements or other land-use over wildlife. This has led to fragmentation of wildlife habitats and populations and reduced ecological connectivity. Policies that have historically excluded communities in biodiversity conservation has led to loss of indigenous practices, and increased incidences of human/wildlife conflicts.

4.4.4.2.2. Energy systems and climate change

Both population and urbanisation have been reported as key drivers in increased emissions in Africa. Africa has among the highest population growth rates in the world. Moreover, urban populations are responsible for more emissions than rural populations. Energy consumption for electricity, transportation, cooking, and heating is much higher in urban areas than in rural villages. At a local scale, urban consumption of energy helps create heat islands that can change local weather patterns and weather downwind from the heat islands. The heat island phenomenon is created because cities radiate heat back into the atmosphere at a rate 15–30% less than rural areas (Torrey, 2004). Primary Energy Consumption in Africa has risen from 261.7 metric tons of oil equivalent (million tons) in 1998 to 435 million tons in 2015 (Statista, 2016) showing a rise of 66% in 17 years. In South Africa, only 16.9% of the final energy consumption was renewables in 2012 (Statista, 2016). At COP 21 in Paris, Parties to the UNFCCC reached a historic agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. Among the global strategies in reducing greenhouse gas emissions from fossil fuels is the development of alternative fuel sources. One such is use of liquid biofuels in the transport sector whose growth in production and consumption will increase due to, among other reasons, mitigation of biodiversity loss (Brenan *et al.*, 2009). Production of such fuels must be both technically and economically viable. Hence, be competitive in pricing; requiring low to no additional land-use; enabling air quality improvement, and; requiring minimal water use (Brenan *et al.*, 2009). Technological application in the exploitation of microalgae could meet these conditions and therefore make a significant contribution to meeting the primary energy demand, while simultaneously providing environmental benefits (Brenan *et al.*, 2009).

Electricity generation using solar energy directly (photovoltaic) or indirectly (concentrating solar power) has grown exponentially worldwide over the last decade (Hernandez *et al.*, 2014). Affordability of solar energy technologies and technically accessible energy for large areas of Africa (Figure 4.26) makes it appropriate to bridge energy needs in the continent. It is estimated that theoretical potential for solar energy for Africa is 1120 Petawatt hours (PWh) being 660 PWh for concentrating solar power and 460 PWh for photovoltaic (Hermann *et al.*, 2014). These potentials have been estimated for areas in the continent that excluded regions critical for biodiversity conservation such as protected areas, wetlands, floodplains, and forests; as well as agricultural land, cities and urban areas (Hermann *et al.*, 2014).

However, solar energy systems installed as utility-scale solar energy enterprises, may have impacts on biodiversity and ecosystem services during construction, operation or decommissioning (Hernandez *et* *al.*, 2014). Locally, concentrating solar power impact biodiversity losses where there is vegetation clearance and gradation of soils; and by fragmenting landscapes, they create barriers to movement of species and their genes leading to regional impacts (Hernandez *et al.*, 2014).

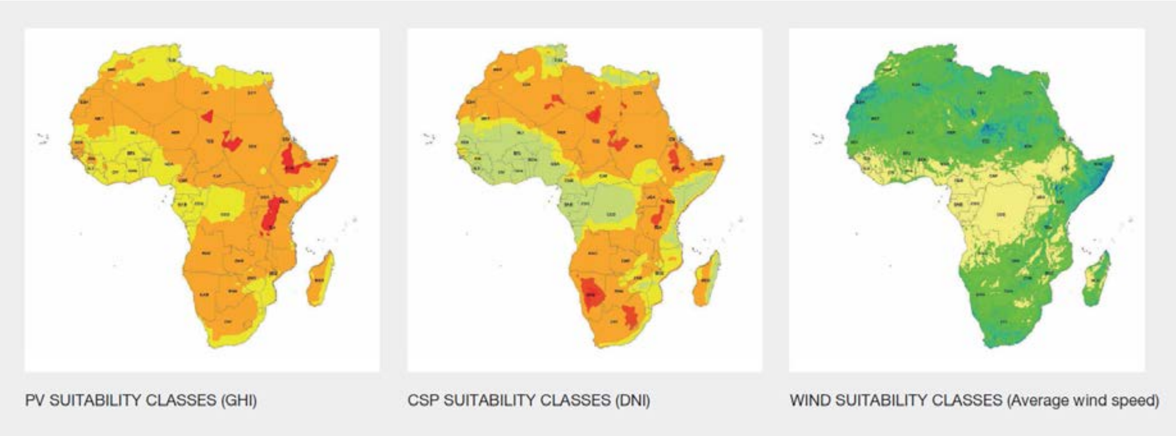


Figure 4.26: Overall resource potential for photovoltaic, concentrated solar power and wind technologies for Africa. Potentials calculated based on solar irradiation and average wind speed. Dark orange and red areas indicate best-suited locations for solar energy systems while dark green and blue areas are best suited for wind. Source: Hermann *et al.* (2014).

Adopting widespread use of utility-scale solar energy enterprises may therefore lead to biodiversity losses at local and regional scales. Solar energy technologies if installed as distributed systems with relatively small capacity (e.g., <1 megawatt) and integrated into existing built environments (e.g., roof-top photovoltaics) will likely have negligible direct effects that adversely impact biodiversity (Hernandez *et al.*, 2014). This would have more beneficial outcomes through reduction in use of fossil fuel in power generation. Studies on impact of other renewable energy technologies on biodiversity show that wind farms affect distribution of birds, with significant effects on non-breeding individuals (Hötker *et al.*, 2006). The birds were also shown to avoid the wind turbines particularly with high hubs; however, the wind turbines did not form a barrier to movement of some species such as cormorants and grey heron that were able to alter direction or height of the flight path (Hötker *et al.*, 2006). Studies in North America (Arnette *et al.*, 2008) show widespread and often extensive fatalities of bats having increased with the development of wind energy. Given the high potential for wind energy in Africa (Mukasa *et al.*, 2013), care should be taken in positioning as this influences collisions. Habitats with high casualty rates include bare mountain ridges, where there is a sharp change in relief (for example at plateau edges), and wetlands (Hötker *et al.*, 2006).

Use of liquid biofuels in the transport sector, driven largely by policies focused on achievement of greater energy security, and mitigation of greenhouse gases emissions has increased globally (Brennan *et al.*, 2009; Webb *et al.*, 2012). Such benefits are yet to be proven from current applications (Webb *et al.*, 2012). Across Africa, the major catalyst for biofuel expansion has been market driven with perceived potential for export to emerging international biofuel markets (Gasparato *et al.*, 2012). This followed the ratification of the European Union Renewables Directive 2009/28/EC leading to large-scale land acquisition by private firms from Organisation for Economic Co-operation and Development (OECD) and non-OECD countries to develop biofuel plantations in several African countries (Gasparato *et al*., 2012). Other drivers have included policies regarding fuel security due to rising oil prices (von Maltitz *et al.*, 2012), economic development, and growing support from bilateral and multilateral donors (Acheampong *et al.*, 2014).

Impacts of biofuel production on biodiversity and ecosystem services can be inferred from the direct impacts of land conversion of natural ecosystems into biofuel feedstock plantations (Campbell *et al.*, 2009). This is of major concern for Africa since large areas of land, totalling 7.55 million hectares have been allocated to foreign investors for biofuel production (GRAIN, 2013). This process, described as land grab (GRAIN, 2013), has consumed large areas distributed within different parts of Africa including the Eastern region accounting for 33% (2.46 million hectares), Western 29% (2.23 million hectares), Southern 14% (1.05 million hectares), Central 8% (601,000 hectares), and the Indian Ocean Island of Madagascar 16% (1.2 million hectares) of total area dedicated to biofuel plantations. In areas where biofuels are grown in existing agricultural land, farmers are compelled to move to marginal lands that are unproductive or infertile (Acheampong *et al*., 2014), hence generating controversy due to their impact on food security (Brennan *et al.*, 2009).

Following the European Union–27 mandate that sets a 2020 target for consumption of biofuels equivalent to more than 40 million tons, global demand for biofuels is now predicted to reach 172 billion litres by 2020, up from 81 billion litres in 2008 (GRAIN, 2013). This may give new impetus for conversion of more land to biofuel plantations increasing concern to potential loss of biodiversity and natures contributions to the people of Africa. Democratization of the energy market would lead to application of unconventional technologies in energy production, e.g., on-site productions on demand that would exclude challenges affecting biodiversity and ecosystem functions and services associated with large production, storage, transport and distribution. Similar technologies may be applicable in water provision, for example, in the extraction from air to assure provision in areas of water deficit. Some existing technologies, for example drones, will in future play important roles in protection of biodiversity.

4.4.4.3. Vulnerability incomes

4.4.4.3.1. Health issues

A study in the North West Province of South Africa revealed that the improved socioeconomic circumstances observed in the wealthiest urban areas were accompanied by superior nutritional status, lower mean blood pressure, better health behaviours (lower smoking, drinking and HIV infection rates), lower measures of all indices of psychological pathology and higher scores of psychological well-being (Vorster *et al.*, 2000). These subjects also had the highest fat intake and serum cholesterol levels. Farm workers were identified as the most vulnerable group, having inadequate diets, highest scores for psychological symptomatology and the lowest scores for psychological well-being (Vorster *et al.*, 2000). Yet, according to UN-Habitat, sub-Saharan Africa has a slum population of about 200 million people, 61.7% of its urban population (AfDB, 2015). Only 84% of the continent's urban dwellers have access to potable water while 54% to sanitation (Brixiová *et al*., 2013). The relatively fewer slums in North African countries is mainly attributed to better urban development strategies, including investment in infrastructure and in upgrading urban settlements. In contrast, SSA has the lowest proportion of urban population (32.8%), but the highest proportion of slum dwellers (65%). Considering different plausible scenarios, Keiser *et al.* (2004) estimate an annual incidence of 24.8–103.2 million cases of clinical malaria attacks among urban dwellers in Africa.

4.4.5. Technology developments and application

Biotechnology, and information and communication technology together with industrialisation of Agriculture and Food Processing technologies will play a key role in improving Food Security without negatively impacting on biodiversity and nature's contributions to people by 2050 when the world population is expected to reach nine billion people. Due to unprecedented growth in human population, the need to increase food production has been technology-dependent based on intensification of management on land newly converted or already under agriculture at a major cost to biodiversity (Deguines *et al.*, 2010). In Africa, this has been accomplished through the use of high-yielding crop varieties, chemical fertilizers and pesticides, irrigation, and mechanization. The process of intensification fell under the general heading of "the Green Revolution," which began in the 1960s with the transfer and dissemination of high-yielding seed (Matson *et al.*, 1997). Agricultural intensification has had negative local consequences, such as increased erosion, lower soil fertility, and reduced biodiversity (Matson *et al.*, 1997; Tscharntke *et al.*, 2005; Firbank *et al.*, 2008). It has also led to the decrease in both pollinator diversity and pollination services (Deguines *et al.*, 2010). Studies in France (Deguines *et al.*, 2010) has shown that benefits of agricultural intensification decreases with increasing pollinator dependence; hence intensification does not increase the yield of pollinator-dependent crops but decreases the stability of their yield over time.

Reduction in plant biodiversity due to intensification leads to changes in the community composition including for beneficial pest complex–herbivorous insects, their natural enemies (predators and parasitoids), and microbial community (Matson *et al.*, 1997) which are fundamental to many functions of soil systems, such as nitrogen cycling, decomposition of wastes and mobilisation of nutrients. The consequence may be higher losses due to high pest densities in monocultures. Agricultural intensification through use of genetically modified crops have been suggested as beneficial to biodiversity as yield improvements on existing agricultural land would lead to reduction in conversion of land into agricultural use (Carpenter, 2011). Also, by decreasing insecticide use, increasing the use of more environmentally friendly herbicides and facilitating the adoption of conservation tillage, genetically modified crops would contribute to increasing agricultural sustainability (Carpenter, 2011). Adopting technologies such as drought or salinity tolerance would alleviate the pressure to convert high biodiversity areas into agricultural use by enabling crop production on suboptimal soils. This would be of particular relevance to sub-Saharan Africa, expected to experience prolonged periods of low soil moisture due to climate change. More research on this technology is, however, necessary as genetically crops may potentially affect the "fitness of other species, population dynamics, ecological roles, and interactions, promoting local extinctions, population explosions, and changes in community structure and function inside and outside agroecosystems (Gertsberg, 2011).

The convergence of food needs and those of energy and water is conspicuous in Africa where 560 million people lack access to electricity in the sub-Saharan area while 621 million rely on solid fuels for cooking (WHO *et al.*, 2009). The challenge therefore is to develop environmentally sound energy systems that will conserve biodiversity and reduce carbon footprint. Renewable energy technologies, though requiring a complex set of environmental trade-offs to develop, would be an alternative to fossil fuel-based energy. Of the renewable energy sources, geothermal power has been considered the most attractive being relatively benign in nature (Mutia, 2010). Most geothermal resources are a challenge to developers since they are located in remote scenic, wild and protected areas (Mutia, 2010). A classic example where geothermal power generation and biodiversity conservation are coupled is at the Hell's Gate National Park in the Kenya's Rift Valley since 1984. However, anecdotal information suggests that wildlife diversity and biomass has been on the decline following recent expansion of the plant generation capacity (Mutia, 2010). This would call for caution in future development of geothermal power plants in protected areas.

4.4.6. Insecurity

Sustainable development thrives best in an environment of good governance, peace and security, but armed conflict remains a major obstacle to development in several parts of the continent (Hanson *et al.*, 2009). Environmental crime can be subdivided broadly into wildlife, pollution and water management crimes; that exploit resources in an illegal manner and destroy the environment in contravention to national, regional and international environmental laws (Nellemann *et al*., 2016; UN, 2016; UNOCD, 2016). The maintenance of an environment of peace and security is therefore one of Africa's foremost development imperatives. Apart from its costs in human and material terms, conflicts impede production, damage infrastructure, prevent the reliable delivery of social services and disrupt societies. Africa is the most sub-divided continent, with small and fragmented economies that undermine the continent's position in the global development arena. In spite of the long-standing commitments and the emphasis placed by African leaders on the process of regional integration, this has been slow and therefore, remains a major challenge for development in Africa (UNECA, 2004; 2005).

Environmental crime is not restricted by borders, and may impact on region's economy and security. For instance, poaching and illegal wildlife trafficking undermines the livelihoods of natural resource dependent communities, damages the health of the ecosystems they depend on, and the criminal activity and corruption associated with trafficking restricts the potential for sustainable investment and development needed in new economic activities and enterprises (UNODC, 2016). A significant proportion of both wildlife and pollution crime is carried out by organised criminal networks, drawn by the low risk and high-profit nature of these types of crime. The same routes used to smuggle wildlife across countries and continents are often used to smuggle weapons, drugs and people. Indeed, environmental crime often occurs hand in hand with other offences such as passport fraud, corruption, money laundering and murder (UNODC, 2016).

Box 4.10: The Environmental Crime crisis in DRC and Somalia

Indeed environmental crimes have been considered grave issues in DRC and Somalia by the UN Security Council, the assessment reveals that the scale and role of wildlife and forest crime in threat finance calls for much wider policy attention, well beyond those regions. Conflicts have been associated with breakdown of social structures among communities. This leads to loss of identity and cohesion among affected people. Since inherent cultural systems of resource use tend to have elements of conservation, their breakdown would result to loss of ecosystem functions and services, and concomitant human well-being (Summers *et al.*, 2012).

Terrorist groups are also known to participate in illegal trade in wildlife products to fund their illegal activities. In case of overharvesting of species populations, there would be loss of ecosystem services to local communities. Conversely, loss of access to biodiversity and ecosystem services associated with resource overuse, e.g. from exclusion of communities from fishing grounds, drying up of inland water bodies for example due to over abstraction in upstream areas, draining of wetlands may also lead to radicalisation of societies and development of terror groups references). The construction of dams upstream of rivers currently focuses on energy and agriculture sectors with little concern of for downstream users. In several cases, the deprivation of water downstream due to lack of socio-ecological water release mechanisms affects livelihoods is a cause of exclusion and conflict. There have been suggestions of possible links between insecurity and access to resources, e.g., drying of Lake Chad and the rise of Boko Haram; The emergence of Somali Pirates/Al Shabab and the departure of Japanese and Korean fishing vessel that were responsible for the decline of fisheries off the Kenya/Somalia coast (Aljazeera Africa, 2010).

4.4.7. Cultural practice and spirituality

In many cultures in Africa decisions about nature arise from the spiritual and ancestral beings who are part of nature, and affect us much more than we are able to affect them. Some people perceive nature as benign and sacred, to be treated with reverence and moderation. Cultural practices among many societies in Africa have exhibited values, beliefs and norms that preserve biodiversity and ecosystems. For example, among the coastal societies in Kenya, important forest blocks have been preserved through the Kaya customary laws. In many other cultures, for example, the Masai, Samburu and Pokot, clans are believed to have blood relations with different animal species, hence, killing of those species are prohibited leading to their preservation. Moreover, local indigenous knowledge held by communities plays an important role in conservation. However, there is need for consideration of the impact of infrastructure development on biodiversity, technological innovations and increasing demand for animal products on culture, spirituality and indigenous and knowledge.

Local and indigenous communities are important partners in conservation, leading to the development of conservation approaches that revolve around indigenous and local knowledge. In the Tharaka area of north-central Kenya, the communities have two levels of justice to protect riparian areas along streams and rivers (Mburu *et al.*, 2016). Women respond first to violation of protected sacred sites by fining transgressors, hence administer the first line of justice while the second level is administered be male elders. The marine waters, sandy beaches, coastal calcareous sand dunes, saline and non-saline depressions, inland ridges, limestone plateau, inland siliceous sand formations, and manmade rain-fed farms in north-western coastal Egypt support diverse floras and faunas, some of which are endemic and threatened (Bidak *et al.*, 2015). The biodiversity here is a source of economic activities and other traditional uses by the Bedouin communities. The sustenance of these goods and services are driven by traditional knowledge and practices (Bidak *et al.*, 2015). The Samburu have natural resources law that rotates around grazing management (Oguge, 2016). This entails (i) segregation of landscape into grazing, settlement and watering areas; (ii) designation of dry season grazing areas; (iii) prohibition of cutting the *Acacia tortilis* tree; (iv) prohibition of burning forests and grasslands. Community elders are the custodians and enforce the law through penalties that vary with regularity of commission.

Cultural practices and spirituality has contributed to enhancement of biodiversity and ecosystem services in the arid and semi-arid area of Tharaka Kenya. The communities here are involved are reverting to traditional knowledge that includes bringing back indigenous seeds for food, trees, fruit-trees, etc. (Mburu *et al.*, 2016). Thus far their efforts have resulted in re-establishment of food crops including millet (3 varieties), sorghum (5 varieties), yams, green grams (3 varieties), cow peas (5 varieties), pigeon peas, pumpkin, a traditional squash (manthanga). This has contributed to food security and increased resilience to climate change as dependent on rain agriculture. The community have also resumed the use of millet in traditional rituals in the sacred sites. This has led to a selection process that targets varieties with characteristics considered unique: i.e., early maturation, large seeds, good seed formation, structure of millet heads, ease of grinding (dhengerembe), agronomic responses to soil moisture (low or high).

While the value of biodiversity is more widely appreciated now than in the past, the pressure on wild lands and unique habitats are also rising rapidly due to encroaching human population and intensified resource extraction. Recent studies (Halmy *et al.*, 2015) has shown that increased sedentary lifestyle of the Bedouins has led to new land-uses such as irrigated agriculture, quarrying, and establishment of summer resorts for recreation and tourism; hence affecting sustainability of the coastal area resources (rangelands and salt marshes) in north-western Egypt (Halmy *et al.*, 2015). Above case studies, though not exhaustive, indicate how indigenous and local knowledge bases contribute to conservation of biodiversity, ecosystem services and livelihoods in Africa. However, future scenarios will need to take into cognisance the development agenda that will embrace urbanisation, extractives and infrastructure. These will impact on biodiversity and ecosystem services directly but also indirectly by affecting communities' cultures and inter-generational knowledge transfer. We also learn from the cases potential to create communities that are economically empowered, socially cohesive, and strong on environmental stewardship based on culture and spirituality.

Community-based conservation is now integrated in biodiversity conservation policies and practices in Africa. It takes various approaches: indigenous and community conserved areas, sacred spaces and communal areas. Indigenous peoples and community conserved territories and areas are spaces governed by them with evidently positive outcomes for the conservation of biological and cultural diversity (Roe *et al*., 2009). IUCN World Parks Congress of 2003 defined them as *"natural and/or modified ecosystems containing significant biodiversity values and ecological services, voluntarily conserved by (sedentary and mobile) indigenous and local communities, through customary laws or other effective means"* (UICN, 2009). Sacred spaces are areas that have spiritual relevance for communities, the zones in which the concept of sacredness is invoked to mark a distinction between the divine and the profane (Roe *et al.*, 2009). In many places, these are recognised as marking a distinction between spaces imbued with spirituality and the spaces of everyday life. They represent the symbolic connection between humanity and the forces that drive nature. Ghana has recognised the oldest community protected area in Africa, the Boabeng Fiema Monkey Sanctuary, created in 1975. Other examples of indigenous and community conserved areas are well known in Africa: the Wechiau hippo sanctuary in north-western Ghana officially recognised in 1999, the Urok Islands community protected marine area in Guinea Bissau recognised in 2005, the village hunting zone of Boumoana in eastern Burkina Faso, the sacred forests in the centre of Benin and the south-eastern of Togo, the villages hunting zones in Central African Republic and the zones of cynegetic interest in the south-eastern and north of Cameroon) (UICN, 2009). In these spaces, revival or modification of traditional practices and/or new initiatives succeed in protecting and restoring natural resources and cultural values of the communities. The communities management decisions and efforts lead to the conservation of habitats, species, genetic diversity, ecological functions/ benefits and associated cultural values, even when the conscious objective of management is not conservation (for example, it may be livelihoods, security, safeguarding cultural and spiritual values). The community-based areas also meet social needs, such as maintaining local culture, increasing opportunities for income generation, and improving health and well-being.

The Communal Areas Management Program for Indigenous Resources, well known as CAMPFIRE, is a program developed largely around the concept of managing wildlife and wildlife habitat in the communal lands of Zimbabwe for the benefit of the people living in these areas. It was one of the first programs to consider wildlife as renewable natural resources, while addressing the allocation of its ownership to indigenous peoples in and around conservation protected areas (Frost *et al*., 2008). During 1989–2001, CAMPFIRE generated over $20 million of transfers to the participating communities, 89% of which came from sport hunting. The scale of benefits varied greatly across districts, wards and households. Twelve of the 37 districts with authority to market wildlife produced 97% of all CAMPFIRE revenues, reflecting the variability in wildlife resources and local institutional arrangements. The Program has been widely emulated in Southern and Eastern Africa. The impact on rural populations was important in terms of social infrastructures. Biodiversity benefits have been witnessed since CAMPFIRE's inception; elephant numbers increased, buffalo numbers are either stable or witnessing a slight decrease, and habitat loss diminished. Another example of community-based conservation can be drawn from Namibia, whereby some nature conservancies cover their operating costs with income derived from trophy hunting and from tourism (Naidoo *et al.*, 2016a). The two activities together provide the greatest incentives for conservation on communal lands in Namibia. A singular focus on either hunting or tourism would reduce the value of wildlife as a competitive land-use option and would have grave repercussions for the viability of community-based conservation efforts in Namibia, and possibly other parts of Africa (Naidoo *et al.*, 2016a).

Despite increasing recognition of community-based conservation initiatives in international conservation policies, there is still great neglect in terms of their effective and appropriate recognition in national policies and practices (Rwabiteta, 2002). When they have no legal recognition within a country, they may also not be recognised or respected by private entities and neighbouring communities. In such cases, they are vulnerable through land and water being appropriated or reallocated for an alternative use. They may also suffer of changing value systems, increased pressure on natural resources and other internal tensions. They are exposed to both external and internal threats: imposed development and resource exploitation processes, such as mining and resource extraction, logging, tree plantation, industrial fishing, sea dredging, land conversion to large-scale grazing or agriculture, urbanisation and major infrastructure (roads, ports, airports, dams, tourism).

4.5. Positive Drivers of Change

This section address measures taken to conserve and use biodiversity sustainably. It considers how positive drivers of change of biodiversity have positively contributed to nature's contributions to people and to good quality of life. There will be a particular focus on protected areas, multilateral agreements, sustainable land management and improved interventions on management of land degradation in Africa. These are measures taken to conserve and use biodiversity sustainably, with tangible benefits for both people and the environment. The section on land degradation and restoration will be kept to a minimum considering that there is a thematic assessment that is entirely focusing on this subject.

4.5.1. Protected areas as a driver of positive change

Protected areas make an important contribution not only to conservation of wild species, but also the ecosystems in which these wild species live (Cantú-Salazar *et al.*, 2010; Muhumuza *et al.*, 2013; Stolton *et al.*, 2015). Africa is one of the continents with of the last remnants of intact natural landscapes that have not been totally transformed by agriculture, human settlements or industrial development. Protected areas contribute to a broad range of socioeconomic and cultural values (ecosystem services or nature's contributions to people) than just conservation of biodiversity (Cantú-Salazar *et al.*, 2010).

In the past, the contributions made by protected areas were taken for granted and their values underestimated especially when they were considered as simple measures to protect particular species or habitats of interest. However, an ecosystem services approach to protected areas received a major boost in the early 2000s due to growing recognition of their socioeconomic value beyond biodiversity conservation (Costanza *et al.*, 1997; MA, 2005; Kettunen *et al.*, 2013). Thus, the conservation of biodiversity (species, genetic diversity within species and of habitats and ecosystems) is critical for ecosystem function and nature's contributions to people (Cardinale *et al.*, 2012).

The proportion of terrestrial and inland waters areas covered by Protected Areas in different regions of Africa are 19.1% in Central Africa, 14.8% in Eastern Africa, 5.8% in Northern Africa, 20.4% in Southern Africa, and 15.5% in Western Africa (Barnes, 2015). Thus only Central and Southern African regions have attained the Aichi Biodiversity Target 11 on terrestrial Protected Areas. Conversely, the continent has attained only 1.7% protection of the marine environment. Basing on area coverage alone as a measure of progress could result in establishment of large protected areas, which have little value and under little threat, neglecting areas where protection is most needed (Barnes, 2015).

The concept of protected areas that involves forceful removal of indigenous people from their land dates back to the establishment of the Yellowstone National Park in the United States of America in 1872. This model was unfortunately been replicated around the world. Even today, indigenous and local communities are often stereotyped as small-scale consumers undermining the important role they play in shaping our environments into eco-sociological landscapes. The last two decades have seen greater appreciation of the role of traditional knowledge and practices in preserving biodiversity, motivated by indigenous peoples desire to live in their ancestral lands and safeguard local food security (Langton *et al.*, 2005; Chibememe *et al.*, 2014). The subsistence role rather than productivity role of diverse indigenous economies including fishing, hunting, herding and agriculture provide positive benefits to the environment. The disenfranchisement of local communities from traditional governance and management role in relation to natural resources is now more and more opposed by international conventions and non-governmental organisations. Several international and national frameworks are now supporting the development of community-oriented protected areas. Through the Convention on Biological Diversity for example, nations are now making considerations in their National Biodiversity Strategy and Action Plans to strengthen indigenous and local community involvement in situ conservation.

Following the World Parks Congress of 2003 in Durban, the theme ‘Benefits beyond Boundaries’ gave impetus to the wildlife conservancy movement, particularly in sub-Saharan Africa (Bushell *et al.*, 2007). The wildlife conservancy was adopted as an effective model to involve local communities in the conservation of wildlife as well as a tool through which to share financial benefits of the same. The model has shown promise, notably in Namibia where cash proceeds from hunting is paid directly to conservancy committees for use in management (Weaver *et al.*, 2008). Other benefits accruing from this situation are improved attitude of local communities towards conservation practice, and increased involvement of locals in the safari hunting industry. The community conservancy model has also seen rapid expansion in East Africa, particularly in Northern Kenya driven by strong donor support and changes in wildlife conservation policy to include community participation. A major difference between this, and the southern African scenario is that the use of wildlife is non-consumptive, save for a few locations where shooting of various game birds is practiced. The primary purpose of the conservancies therefore, is to provide and maintain a tourism product. This fundamental basis has been the root of many challenges including loss of grazing rights due to creation of exclusive tourist zones, erratic income due to the fickle nature of the tourism industry, amongst other challenges. The most important challenge has been the introduction of a livelihood dependent on skills, contacts and other resources that local communities do not have or cannot access. The resultant discontent has occasionally manifested in violent resource competition and failure of tourism enterprises (Ogada, 2016). The cautionary lesson of these outcomes is that the sustainability of community conservancy model depends on its application, higher resolution to accommodate the socio-economic and cultural differences that occur across sub-Saharan Africa. Community-based protected areas have involved especially no-take zones for certain fisheries resources, managed entirely by communities. In East Africa, Beach Management Units are common around freshwater and marine resources for co-management and governance of fisheries resources. The success of any community-oriented protected area system depends on respect for the rights of access communities while at the same time ensuring wise and sustainable use (Kanyange *et al.*, 2014).

However, in cases of conflicting legislations in co-management of Protected Areas, governance dilemmas occur leading to habitat degradation and unsustainable harvest of ecosystem goods, for example in the Mount Marsabit National Park in Kenya (Roba *et al.*, 2004; Robinson, 2013). This policy approach has been severely criticised largely due to a) low added value for local communities, b) short-term vision, integrated projects of conservation and development that worsen conservation problems because they generate new inhabitants and therefore population pressure and overexploitation of resources, c) persistence of competition problems between hunting and, d) agriculture, ambiguous effects on incentives for conservation (Iritie, 2015). Although these areas are protected, many of them can go through periods of heavy poaching as described in section 4.2.2.2.3 on protected areas in terrestrial and inland waters.

4.5.1.1. Protected areas in terrestrial and inland waters

The distribution of a strong network of protected areas spreads across Africa (Wegmann *et al.*, 2014; Figure 4.28). Clear evidence of the role these have played in the conservation of biodiversity has been demonstrated. The rates of stocking of protected areas, especially with megaherbivores are a critical determinant of vegetation cover change within versus outside protected areas (Owen-Smith, 1988). In addition, contrasting land-use adjacent to protected areas causes fragmentation and loss of habitats. High vegetation cover loss has been recorded in some protected areas compared to their surroundings, thus requiring particular conservation attention as this makes connectivity among protected areas very difficult (Wegmann *et al.*, 2014; Figure 4.27).

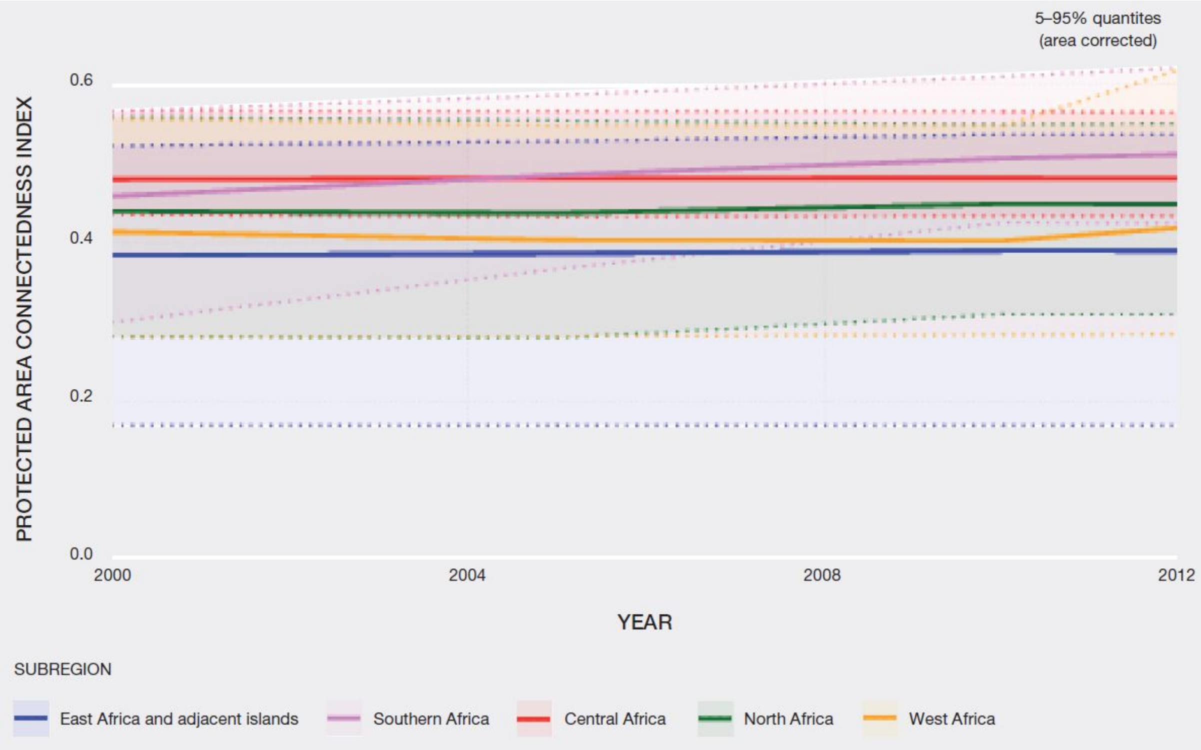


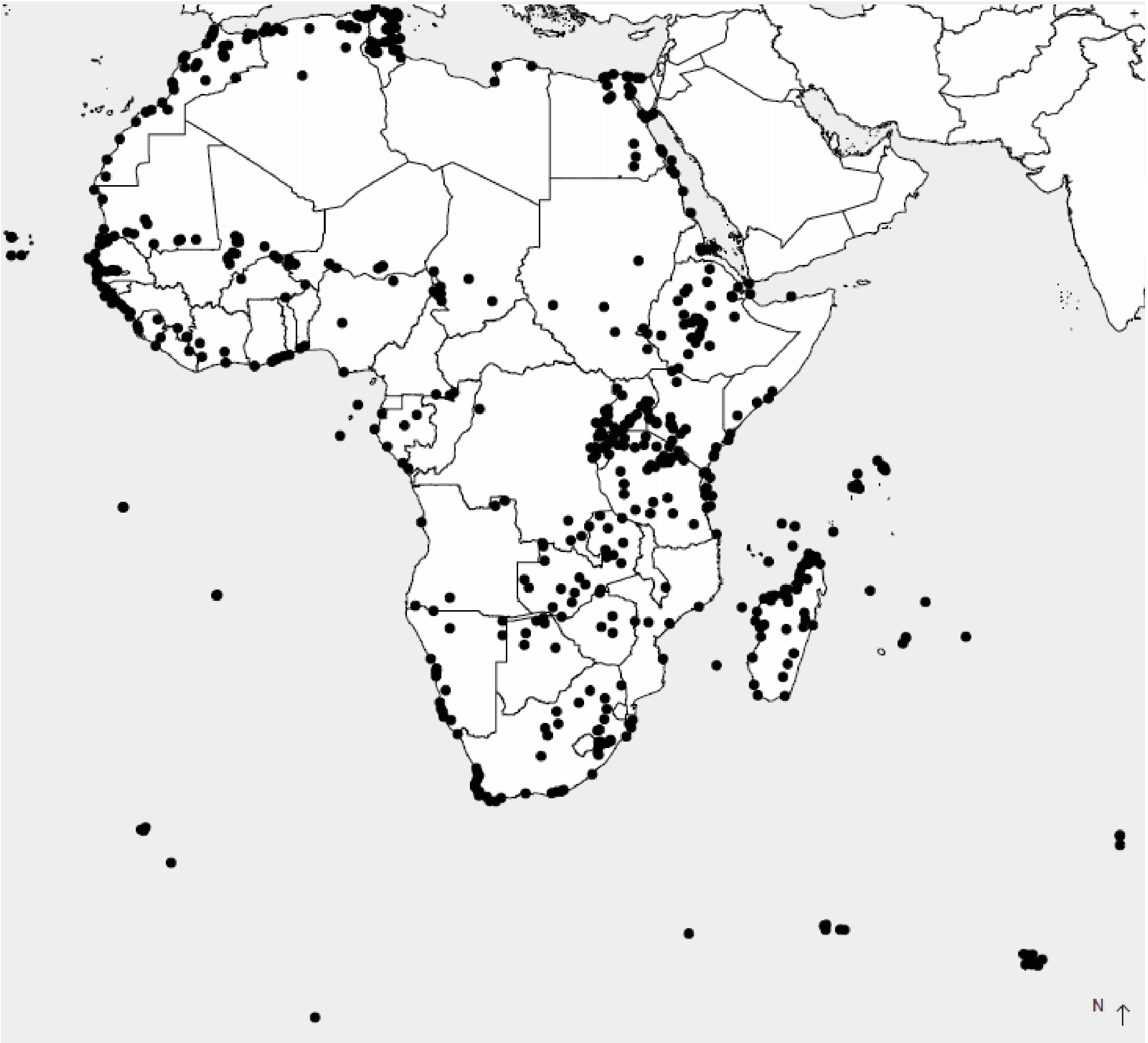
Figure 4.27: Africa's Protected Area Connectedness Index (PARC-connectivity) in 2012. Source: GEO BON-CSIRO, The figure prepared by Task Group on Indicators and Knowledge and Data Technical Support Unit).

Protected areas however have their limits. Western *et al.* (2009) found that census conducted on Kenya's wildlife populations showed declines in wildlife populations within protected area and adjacent reserves over a 30-year period. In some protected areas the declines were similar to non-protected areas (Western *et al.*, 2009). Losses were in part due to poor coverage of seasonal ungulate migrations. It is thus important to monitor and quantify impact of conservation policies and strategies on wildlife populations in particular and biodiversity in general (Western *et al.*, 2009; Lindsey *et al.*, 2014). Thus an integrated landscape approach to conservation planning is important in ensuring suitable habitats for wildlife is conserved in state, private and community-based conservation measures. It is also important to note that many African protected areas are not functioning as effectively as originally intended, in part due to limited resources to maintain these areas as strictly protected and/or to enforce relevant legal frameworks (Lindsey *et al.*, 2014). According to Lindsey *et al.* (2014), other reasons include: a) rapidly expanding human populations, poverty and open-access systems resulting in widespread bushmeat poaching and habitat encroachment; b) underfunding of responsible conservation agencies resulting in inadequate law enforcement; c) reliance of the same agencies on extracting revenues from concessionaries who manage operations within protected areas; d) poor efforts in access and benefit sharing with communities; amongst others. The combined effect of these challenges has been a major reduction in wildlife densities in many protected areas (Craigie *et al.*, 2010) and related poaching and illegal trade in wildlife products (Ingram *et al.*, 2017). A major knowledge gap in this arena, which needs to be addressed is the impact of sport hunting on the populations of various species of megafauna in Africa. The current assumption of nil effect is scientifically untenable.

The Convention on Biological Diversity's Aichi Biodiversity Target 11, on protected areas, includes aspirations of reaching 17% protected area coverage of the world's terrestrial and inland waters and 10% of coastal and marine areas, by 2020 (Ervin *et al.*, 2010). By 2016, estimates of the chances of meeting these goals by the deadline, showed that terrestrial and inland waters is likely to be achieved in advance, and has exceeded projection for coastal and marine protected areas within national jurisdiction (UNEP-WCMC, 2016). The African continent as a whole is on track to achieving this goal with the current 15.4% coverage. Two out of five subregions, namely Eastern Africa (20%) and Southern Africa (20.8%), have exceeded the 17% target (Figure 4.28), while Central Africa at 16.6% is close to achieving this. Even though Northern Africa has less than 10% at the moment, if priority actions proposed in Morocco for 20 new protected areas and 30 Ramsar sites, will enable the subregion to remain on track. There are commitments to other conventions such as Ramsar showing a distribution of important bird areas and wetlands of international importance (Box 4.4) and the African Eurasian Waterbird Agreement between parties to the Convention for Migratory Species. The coverage of area by protected areas has been suggested to be a poor measure of progress, as also recognised by Aichi Target 11 (Barnes, 2015), and a more holistic approach of Key Biodiversity Areas has been proposed (Brooks *et al.*, 2016).

Box 4 11 Important Bird Areas and Wetlands of International Importance. Source: BirdLife International (2002).

In Africa, over 1,250 sites have been identified as Important Bird Areas (IBAs) (see figure below), these are locations where networks have been formed for conservation of birds, other biodiversity and wider ecosystems and their services. IBAs have in many countries formed the basis of designation of wetlands of international importance, under the Ramsar convention. This is due to the recognition that the presence of significant numbers of waterbirds in a wetland is often an indicator of the importance of the site for many other features as well, including values and functions of great relevance for people (BirdLife International, 2002).



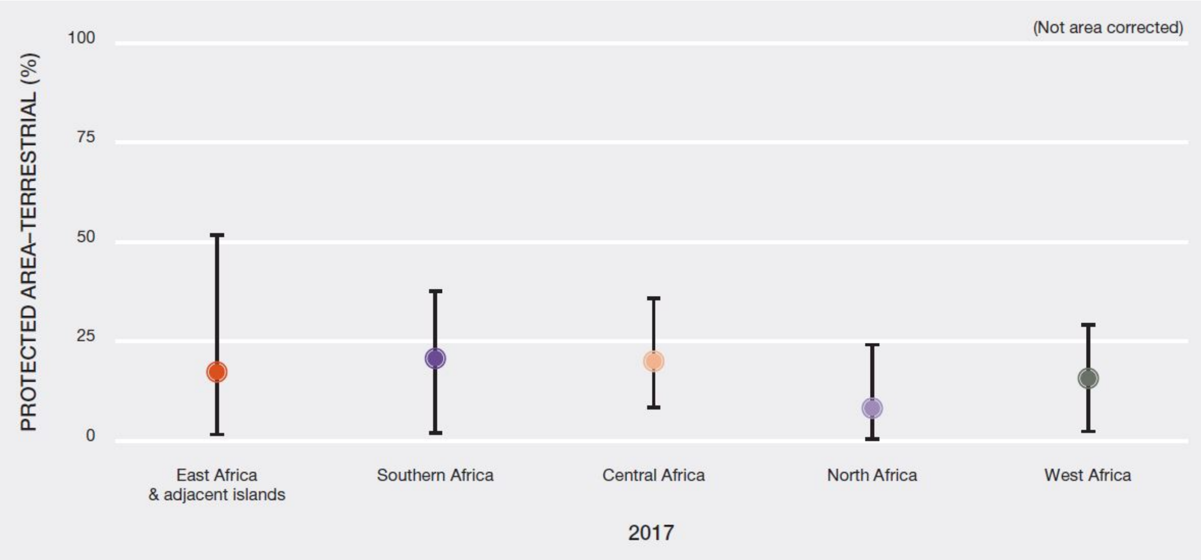


Figure 4.28: Subregional status of terrestrial protected area coverage in Africa, 2017. Note: circles represent mean and bars represent confidence intervals. Source: UNEP-WCMC *et al.* (2017). Figure prepared by the IPBES Task Group on Indicators and Knowledge and Data Technical Support Unit.

4.5.1.2. Coastal and Marine protected areas

Africa's Marine Protected Area (MPA) coverage is relatively low compared to Western European and Others Group where larger MPA networks exist. At subregional level Northern Africa has the largest coverage (9.1%), followed by Central, Southern, Western and Eastern Africa. At national level, DRC, Namibia and Mauritania, South Africa has the most area protected (Figure 4.29).

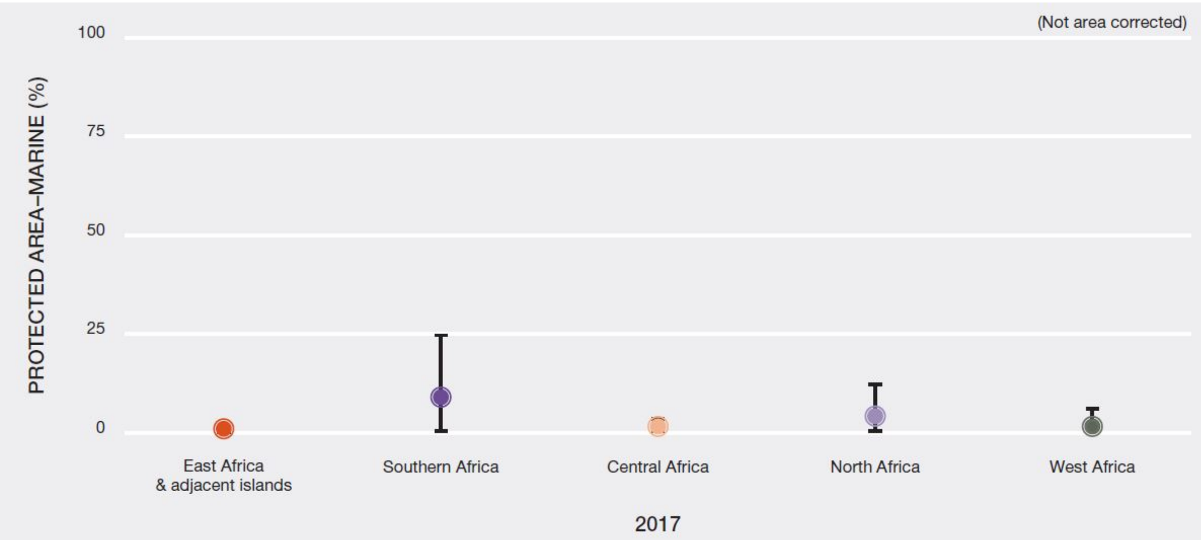


Figure 4.29: Subregional status of marine protected areas in Africa, 2017 (Note: circles represent mean and bars represent confidence intervals). Source: UNEP-WCMC *et al.* (2017). Figure prepared by the IPBES Task Group on Indicators and Knowledge and Data Technical Support Unit.

4.5.2. Multilateral Environmental Agreements

The major environmental concerns or issues in Africa include: climate change, land, freshwater, oceans and seas and biodiversity (UNEP, 1997; UNEP, 2012). These concerns have to a large extent guided the continent's engagement with Multilateral Environment Agreements (MEAs), whereby the ratification of an MEA often reflects the importance that individual countries place on the issues it address. United Nations Convention to Combat Desertification, for example, is one of the most important environmental MEA processes for Africa. The special emphasis on the situation in Africa in the convention text has resulted in its receiving a high degree of political commitment and extensive support; in fact all African states are parties to the convention.

The United Nations Framework Convention on Climate Change (UNFCCC) is also of high priority in Africa. The Paris Agreement on climate change adopted in December 2015 further reinforced global commitments for the environment. UNFCCC parties agreed to hold the rise in average temperature to well below 2°C above pre-industrial levels—and to try to limit it to 1.5°C—while embracing the target of zero net emissions of greenhouse gases in the second half of this century. Nineteen nations have endorsed the Africa Clean Energy Corridor, which could increase the development of renewable energy projects from their present 12% of the East and Southern Africa Power Pool to at least 40 % by 2030. The Convention on Biological Diversity has led to the formulation of biodiversity plans and strategies, especially in countries where the depletion of tropical rain forests and the rapid disappearance of biodiversity has attracted national and international attention. Convention on International Trade in Endangered Species of Wild Fauna and Flora closely related to the Convention on Biological Diversity, has seen the development of national programs in much of Africa to help in the sustainable utilization and trade in wildlife (UNEP, 1997).

The Ramsar Convention on wetlands of international importance has 28 contracting parties in Africa. The Convention requires that parties designate at least one national wetland for inclusion in the List of Wetlands of International Importance. The floodplains of the Zambezi River and the Okavango Delta are among Southern Africa's major wetlands, providing a wide range of functions such as water and nutrient retention and flood control. They are also important for tourism. Other notable sites include the coral reefs of Tongaland and the St Lucia System (South Africa); the Kafue Flats and Bangweulu Swamps (Zambia); and in East Africa, the Lake George ecosystem in western Uganda and Lake Nakuru in Kenya (UNEP, 1997).

4.5.2.1. African Union Agenda 2063

In May 2013, African leaders met in Addis Ababa, Ethiopia to celebrate milestones and make development commitments for the next 50 years, producing the Agenda 2063. This agenda is a strategic framework for the socio-economic transformation of the continent building on existing growth and development initiatives. The Agenda aims at ensuring Africa remains focused and on track in its socio-economic development ideas within a rapidly changing world. These ideas are summarised under seven aspirations themed, the “Africa We Want”. The adoption of the 2030 Agenda for Sustainable Development and its associated Sustainable Development Goals, two and a half years later (in January 2016), ushered in a new era of global partnerships for sustainable development. This new development was perceived by Africa as an opportunity to consolidate its priorities and concerns. The Agenda 2030 is indeed reflective of the aspirations of Agenda 2063. In the environment pillar of sustainable development, for instance, goal seven of Agenda 2063, which focuses on environmentally sustainable and climate resilient economies and communities, is aligned with the implementation of several Sustainable Development Goals on biodiversity, forests, oceans, and climate action among others (AU, 2015).

4.5.3. Sustainable land management

Sustainable land management (SLM) is defined as a knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet rising food and fibre demands while sustaining ecosystem services and livelihoods. Sustainable land management is seen as the response mechanism to counter degradation of biodiversity and the provisioning of environmental services. It should be viewed as the driver of enhanced biodiversity in ecosystem service flows and is necessary to meet the requirements of a growing population. Improper land management can lead to land degradation and a significant reduction in the productive and service (biodiversity niches, hydrology, carbon sequestration) functions of watersheds and landscapes. (World Bank, 2008). In effect Sustainable land management is a positive driver to prevent or reverse degradation and to ensure communities can continue to reap sustainable flows of ecosystem services from the land. According to the World Bank (2008), SLM should:

- Foster an enabling environment for broad-based and sustainable rural growth;
- Promote agricultural productivity and competitiveness;
- Encourage nonfarm economic growth;
- Improve social well-being, manage and mitigate risk, and reduce vulnerability; and,
- Enhance sustainability of natural resource management.

Sustainable land management can and should be operating at a number of different spatial scales ranging from individual agricultural fields to entire catchments or countries. As such it is applicable to dryland crop agriculture, irrigation, and rangeland and forest management. The tools and methods used as well as the actors involved will change between scales, though in all cases the actual land-users would be key roll-players, with or without support from external agencies. There is a growing interest in using landscape level approaches that consider planning at a landscape of catchment level and that integrate across a number of land-use activities (e.g., cropping, animal husbandry, rangeland management, forestry and water management). Ensuring optimal trade-offs between different land-uses (often referred to as the land-use nexus) is also important and would consider aspects such as maintaining biodiversity, food, fibre fodder and fuel provision.

The United Nations Conference on Sustainable Development (Rio+20) adopted the document “the future we want”, which recognised in paragraph 206 *the need for urgent* action to reverse land degradation. In view of this we will strive to achieve a land-degradation neutral world …” (UNCCD, 2012). In response the UNCCD has set an ambitious target for zero net land degradation by 2030 (UNCCD, 2012). Signatories to the convention would be expected to aim for this target. This would be achieved by either reducing degradation before it occurs or by reclaiming already degraded land. In essence zero net land degradation means that rates of restoration need to equal or exceed rates of land degradation. Defining and measuring net zero degradation is, however, contentious (Kaphengst, 2014; Stavi *et al*., 2014; Chasek *et al.*, 2015). Monitoring the degradation status of land, particularly at the global level, remains a key challenge (Cherlet, 2012). Operational aspects of implementing programmes to halt degradation, or restore degraded land, are also challenging and require political will as well as financial and technical resources(Stavi *et al*., 2014; Chasek *et al.*, 2015).

The World Overview of Conservation Approaches and Technologies (Liniger *et al*., 2007) is a global initiative that collects and documents information on sustainable land management practices so that these can be easily shared. A number of additional resources are available in support of sustainable land management including from the World Bank and TerraAfrica (Liniger *et al.*, 2011). The TerraAfrica program of the Global Environmental Facility was the major Global Environmental Facility funding stream in support of Sustainable land management in Africa.

Africa, as the least developed continent, has a huge need to achieve economic development. This places a tension between development and environmental issues. It is inevitable that large amounts of large-scale land transformation are going to take place. The objective of Sustainable land management is to ensure that the exploitation of natural resources is done in such a way as to sustainably achieve both objectives. Many Sustainable land management practices can simultaneously enhance crop and livestock yields whilst reducing the level of degradation. This would be through practices such as rainwater harvesting, conservation agriculture, small-scale irrigation management, integrated soil fertility management and agroforestry (to name but a few) (Liniger *et al.*, 2011).

4.6. Conclusion

Habitat conversion and loss pose a considerable ecological problem in Africa. Conversion of forest and rangelands for agriculture, mining and urban development has led to habitat loss, degradation of catchment areas and soil erosion leading to loss of biodiversity and livelihoods. The fragmentation that results from various land-uses contributes to biodiversity loss because many wildlife species are migratory and conservation areas do not provide sufficient habitat. This is leading to loss of biodiversity, especially of vulnerable species with narrow ecological niches, as natural habitat is partially or completely lost. Overharvesting of wild species despite their endemism and conservation status represents a serious threat to Nature's Contributions to People in Africa. Global markets and demand for wildlife products have severely challenged national policies because of the prevailing poverty, illicit trade and the high value of these products in the global markets. Illicit trade in wildlife is linked with international criminal gangs and terrorist organisations.

The spread of invasive alien species in terrestrial and aquatic ecosystems is rapidly increasing in Africa with impacts on native species, rural production and livelihoods. Invasive alien species have become a major ecological, social and economic problem despite the existence of legal measures and substantial funding to control them. The magnitude of the problem varies from ecosystem to ecosystem, and from country to country. Increased mobility and human interaction have been key drivers in the spread of invasive alien species. Pollution also contributes to loss of nature's contributions to people in Africa especially in freshwater ecosystems. Population growth is associated with an increased use of a large number of chemicals and pollutants including prohibited Persistent Organic Pollutants such as DDT under intensive crop production systems. Most of these agrochemicals find their way into water bodies, air and soil, causing unacceptable loss of pollinators, and freshwater flora and fauna including soil enriching microbes.

Africa is warming faster than the global average and it is likely to warm by an average of 1.5º to 3ºC this century. There is likelihood of profound impacts on species distribution within the terrestrial environment, partial loss of the vast African savanna with its iconic fauna and flora, and collapse of coral systems. Climate change will impact human health by increasing range and seasonal duration of malaria, neglected tropical diseases, and incidences of zoonotic transmission of communicable diseases, for example, Ebola. It is also a cause of emerging infectious diseases for livestock and wildlife such as the rift valley fever, Anthrax and Canine Distemper; and for plants. Projections based on a continuation of current policies and practices indicate that climate change is expanding the habitat ranges of several these disease vectors. Fire consumes significant amounts of biomass across Africa every year and plays a positive role in shaping the structure and composition of various fire driven ecosystems. Fire suppression has negative effects on biodiversity in such ecosystems. Fire, coupled with browsing, can be used as a tool to suppress increases in woody plant encroachment. Protected areas make an important contribution to conservation of wild species and Nature's Contributions to People in Africa. In Southern Africa, the main drivers of development are shifting from extractive industries such as mining and exploitation of natural resources to sustainable ecotourism, resulting in improved land-use management due to a prevailing conservation ethic and associated economic benefits. Agreements for transboundary natural resource management such as with parks and water management (dam construction for cross-boundary water and energy supply) and others may also a result from this shift, e.g., Transfrontier Parks.

Urban migration is leading to increased demand for services and infrastructure development with communities requiring improved water supply, pollution control and waste management as well as energy supply for households and for industrial development. Demand for food, water and energy in urban areas has increased with urbanisation. The economic dynamics, social links and environmental synergies occurring across the urban-rural continuum underpins their interdependencies; with the flows and functions being asserted through access to food, ecosystem services, social services, transport, employment and markets. Urban communities are producing large quantities of solid and other wastes that are leading to environmental pollution. Africa's development trajectories are leading to improvement in quality of life, driven by growing investment in infrastructure development and expansion of modern urban human settlements, sanitation and energy supply. However, this is also putting enormous pressure on nature and nature's contributions to people. Higher economic growth among many African countries (>5% per annum) and growth in per capita income is driving demand for goods and services provided by nature. At national level, there are major investments in large investments in big infrastructure ports, roads, rails, telecommunications, high voltage electric power transmission lines, water distribution and sanitation, and planned petroleum pipelines across the region. The development of infrastructure puts enormous pressure on nature as land is cleared and resources are overutilized.

Changes in land ownership and an increase in land acquisition (land grabs) to meet local, national and global food and renewable energy demand are driving changes in nature and nature's contributions to people. Land ownership is shifting from small-holder farmers to large-scale commercial farming and land-use (or the focus of production systems) is shifting from subsistence agriculture to supply a growing international biofuels industry, influenced by policies in rich nations. This is contributing to land conversion as critical ecosystems including wetlands, rangelands and forests are being converted into agricultural land for food or energy markets. There are also trade-offs in the use of land for the production and supply of food, water, energy and other land-uses such as mining and development of human settlements (food, water, energy nexus). Sustainable development thrives best in an environment of good governance, peace and security whereas armed conflict has substantial costs in human and material terms, hinders production, damages infrastructure, prevents the reliable delivery of social services to communities. Organised criminal networks carry out environmental crimes (poaching, illegal wildlife trade, illegal trade of timber and non-timber forest products) across borders and affect national economies, security and threaten sovereignty of some countries. Environmental crimes undermine the livelihoods of natural resource dependent communities, damage the health of the ecosystems they depend on, and restrict potential investment in development of affected areas. Terrorist and rebel groups participate in environmental crimes in order to fund their illegal activities. The insecurity that results from their illegal activities leads to localized biodiversity loss, especially diversity of wild fauna and, undermines Africa's conservation legacy and livelihoods of resource-dependent communities.

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Chapter 5: Current and future interactions between nature and society

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Executive Summary

Scenario planning is a key approach for exploring the longer term consequences of nature-society interactions, and are used to inform policy making about the potential risks, opportunities and trade-offs of different possible future pathways of change. Scenarios do not aim to forecast or predict the future, but rather to highlight how different potential futures may unfold and thereby assist in the formulation and implementation of policies and interventions. This assessment identified 355 scenario studies published since 2005 that have explored the future of biodiversity and Nature's contributions to people (NCP) across Africa. The different scenario studies were clustered and compared in terms of five major alternative trajectories (or archetypes) of future change across Africa, respectively emphasising markets, policy reform, security (fortress world), and regional and local sustainability {5.1.1, 5.2.1, 5.3}.

For Africa as a whole, drivers related to population, urbanisation, consumption and natural resource use are expected to increase under all five major scenario trajectories assessed. Similarly, the impacts of climate change impacts in Africa are expected to increase under most scenarios (5.4, *established but incomplete*). However, substantial variation in all key drivers is expected between regions and different scenarios. The largest populations on the continent are expected under *Fortress World* scenarios, but remain largely rural with high direct dependence on natural resources, leading to sustained pressure on biodiversity and NCP. The lowest populations are expected under *Policy Reform* scenarios, and are expected to be largely concentrated in large urban centres. However, increased wealth, consumption and global trade under this scenario also leads to high demand for food and other resources across Africa {5.4} (*established but incomplete).*

Under most future scenarios, Africa is increasingly interconnected with the rest of the world through global markets and trade *(established but incomplete)*. Connections between different subregions in Africa are also likely to increase. Consequently, decisions and activities elsewhere in the world and in different parts of the continent may increasingly affect human well-being, NCP and biodiversity across Africa (5.8, *established but incomplete*). Large-scale resource extraction by multi-national companies are expected to lead to land grabbing, increased conflict, displacement and migration under several scenarios (5.4.4; 5.8, established but incomplete). While global trade has the potential to catalyse further economic and social development in Africa, this assessment suggests that under many scenarios the primary beneficiaries are overseas markets and investors. In the longer term, ecosystem service provision and local food security in Africa may be undermined unless trade and the distribution of its benefits are carefully governed {5.8}.

The impacts of human activities are expected to result in further losses of terrestrial, freshwater and marine biodiversity, as well most reductions in many provisioning and regulating services across Africa *(established, but incomplete)*. In the short-term, habitat loss through land-use change may have more severe consequences for biodiversity and NCP than a changing climate. Current protected areas across Africa are generally not well aligned with future climate-related range shifts of species, implying increased resource needs to meet conservation objectives in the future. Although there is variation in the level of water availability across different scenarios and regions, water stress in Africa is expected to increase under all scenarios, particularly in the southern African region. Similarly, pollination services and regulation of climate and storm protection in Africa are likely to decrease under most scenarios. On the other hand, terrestrial food production and energy provision through biofuels is expected to increase under most future scenarios {5.5}.

Increasing trade-offs are expected in the water-food-energy nexus. The increase in trade-offs is particularly pronounced under scenarios that emphasise economic growth (5.7; 5.8, *established but incomplete*). There are more opportunities for synergies under scenarios that emphasise sustainability and the adoption and enforcement policies that increase and modernise agricultural production and access (5.7 *established, but incomplete*). Under all scenarios, achieving the goal of eradicating hunger is unlikely without compromising water quality. Energy security and access is best met under scenarios that focus on mitigating the impacts of climate change through proactive climate action and efforts to enhance regional sustainability (5.4; 5.7, *established but incomplete*).

Overall levels of human well-being are expected to improve under most future scenario trajectories, but Africa continues to face unique challenges *(established but incomplete)*. Poverty is generally expected to decline, but major pockets of poverty persist, particularly in rural areas. Equity similarly shows mixed results, with progress towards greater equity threatened by patchy development across Africa and asset capture by foreign companies. Health is not expected to improve significantly under most scenarios, though health concerns shift from lack of access to food and medicine to problems associated with modern lifestyles (e.g., diabetes, air pollution). Security and freedom of choice are only expected to improve significantly under very particular scenario conditions where global cooperation and African national governance align effectively {5.5}.

Alignment of the Agenda 2063 aspirations, Sustainable Development Goals and Aichi targets can facilitate interventions that achieve multiple transformative outcomes by linking the conservation of biodiversity and NCP with enhanced human well-being in Africa *(established but incomplete)*. Scenarios that prioritise sustainable development trajectories, with strong regional integration, collaboration, proactive and inclusive governance, show the potential for avoiding dependencies and lock-in behaviours associated with scenarios where rapid exploitation of the natural environment for short-term gains are promoted. While all of the scenarios involve trade-offs, scenarios that involve the development of strong regional institutions and good governance offer the best options for maintaining ecological integrity in support of human well-being and sustainable development {5.7}.

There are currently clear gaps in the type and distribution of scenario studies in Africa, with some subregions—such as central, northern and western Africa—being particularly poorly covered *(established but incomplete)*. Most of the studies assessed in this chapter have addressed future changes in southern Africa (37%) and eastern Africa (18%). Almost 50% of the studies focused on local scales, while 26% covered multiple countries, and 18% are part of global scenario exercises. Only 11% of the assessed studies were conducted at the national scale, which is arguably the most useful scale for decision-making. The majority of the studies (80%) have had a broad exploratory focus, with only 24% focused on assessing specific policies or interventions. Furthermore, most studies (46%) used existing scenario storylines from other (often global) studies to explore future impacts on biodiversity and NCP in Africa; only 14% developed new integrated scenario storylines (5.2.2, *established but incomplete*). Furthermore, the links between NCP and human well-being are not often explored in much detail beyond climate change impacts on disease vectors and livelihoods {5.5}.

Scenario studies in Africa are heavily biased towards modelling climate change impacts, and do not sufficiently incorporate broad stakeholder participation or indigenous and local knowledge (ILK). Only 12% of the studies assessed included a participatory approach, and only 3% integrated ILK to some extent. In contrast, modelling exercises have been widespread (90% of studies), but mostly focus on climate change impacts (60%). The main models used in African scenario studies are correlative models (48%), followed by process-based models (29%) and expert-based models (8%)

(5.2.2, *established but incomplete*). There is a critical need to broaden the scenario approaches used in the region to better incorporate ILK and participatory approaches.

Concerted efforts are needed to mobilise financial resources and build the capacity of African researchers, policymakers and institutions to understand, carry out and use scenario analyses. Although over half (56%) the studies assessed included at least one African-based author, only 19% of the studies involved only authors affiliated with African institutions. South Africa is by far the most productive African country, contributing to 29% of all studies. However, there is very little collaboration between South Africa-based authors and authors from other African countries (section 5.2.2, *established but incomplete*). Existing regional and international expertise should be leveraged to train a wider set of researchers in the use of scenario methods, and in communicating outputs of scenarios to decision-makers (5.2.2, *unresolved*).

5.1. Introduction

This chapter focuses on how interactions between nature and society could shape a range of different possible future trajectories of change across Africa over the coming decades, and the potential implications for nature, nature's contributions to people (NCP), and good quality of life as defined in the IPBES conceptual framework (Díaz *et al.*, 2015). We specifically explore the potential for achieving key sustainability and development-related targets in the region under different possible future development pathways, including the 2020 Aichi biodiversity targets[4], the 2030 Sustainable Development Goals (SDGs)[5], and the 2063 AU agenda (AU, 2015). Ongoing global and regional changes such as changing land-use patterns and climates discussed in Chapter 4 are likely to have far-reaching effects on NCP such as food, water and livelihood security, and the biodiversity and ecosystems that underpin them, as highlighted in Chapters 2 and 3. At the same time, human responses to global change, especially in rapidly developing regions like Africa, are likely to feedback to amplify, dampen, or redirect these changes in unexpected ways that cannot be predicted (Gunderson *et al.*, 2002; Biggs *et al.*, 2015a). While Africa has shown extraordinary growth across many development indices over the past decade (World Bank, 2013, 2016), it is therefore very difficult to know if these trends will continue, and what social, political, environmental and economic conditions will be like across Africa in the future, particularly in the medium- to long-term.

Scenario planning presents a particularly useful and appropriate tool to explore the longer-term future development of nature and society and their interactions (Bennett *et al.*, 2003; IPBES, 2016). The starting point for scenario planning is that the future is not predetermined; instead, a variety of different futures are possible, depending on what decisions and actions are taken, what unexpected chance events and shocks occur, and how different interactions and feedbacks between nature and society unfold (Alcamo, 2001). Scenario planning is based on the assumption that the longer term future of large complex systems cannot be predicted or projected, and that focusing on a single most likely or best guess future is counterproductive as it causes scenario users and decision-makers to ignore large, important uncertainties and the potential for game-changing events and actions (Peterson *et al.*, 2003). Instead, scenario planning assumes that the best approach to understanding complex futures is to explore a range of different plausible pathways that could unfold, given different possible future conditions and system interactions (Derbyshire *et al.*, 2017). Rather than predicting a single, most likely future, scenario approaches therefore aim to develop a set of (usually 3–5) very different plausible futures that can broaden perspectives and alert researchers, practitioners and decision-makers to possible future risks as well as opportunities, and thereby assist in the formulation and implementation of policies and interventions that could be robust under multiple future conditions (IPCC, 2014; IPBES, 2016; UNEP, 2016).

In this chapter, we undertake a comprehensive assessment of scenario studies that have been conducted to explore the future of the African region. The objective of the assessment is to explore the implications of different possible evolving relationships between nature and society over the coming decades, particularly in terms of key drivers of change, and impacts on biodiversity, NCP, human well-being, poverty and inequality. We specifically highlight the potential implications for the SDGs, Aichi targets and AU agenda, as well as priority issues such as climate change and the food-water-energy nexus that have been identified within the African context (Chapter 1). The assessment presented in this chapter aims to inform and strengthen the science-policy interface in Africa, and set the stage for exploring governance and decision-making options in Chapter 6. However, before presenting the approach and

[4]https://www.cbd.int/sp/targets/
[5]https://sustainabledevelopment.un.org/sdgs

results of our assessment, we provide a short overview of scenario approaches and concepts. The concept of "scenarios" is understood in several different ways and this is often a source of confusion, particularly within the African context where researchers, policymakers and practitioners are not necessarily familiar with scenario approaches.

5.1.1. What are scenarios and how are they used in decision-making?

Scenarios are plausible stories about how the future might unfold, and usually refer to plausible futures for indirect or direct drivers, or to policy interventions targeting these drivers (IPBES, 2016). Scenarios are distinguished from other approaches to future assessment, such as forecasting and risk assessment, by being specifically intended for situations in which the factors shaping the future are highly uncertain and largely uncontrollable (Peterson *et al.*, 2003). While assessments of status and trends (Chapter 3) rely heavily on the analysis of observations and are (with some limits) well understood by policymakers and stakeholders, good scenario work requires moving beyond projections based on past observations and trends to accounting for completely new potential relationships between social and ecological systems that may result from new technologies, policies, institutions and values (Derbyshire *et al.*, 2017).

Different policy and decision contexts require the application of different types of scenarios (IPBES, 2016, Figure 5.1). *Exploratory scenarios* examine a range of plausible futures based on potential trajectories of key drivers and can contribute significantly to high-level problem identification and agenda setting, as they provide a means of dealing with high levels of unpredictability and uncertainty. Exploratory scenarios typically involve the development of coherent, integrated storylines that aim to account for the relationships and dependencies amongst key drivers (Zurek *et al.*, 2008). Such integrated storylines, for instance, the Intergovernmental Panel on Climate Change (IPCC) scenarios, or the Millennium Ecosystem Assessment scenarios (MA, 2005), do not investigate the effects of varying individual drivers, but rather consider how multiple, interconnected drivers are likely to co-evolve. For example, in most storylines, population growth tends to be correlated with greater carbon emissions and climate change, unless major technological advances are assumed. Given the substantial time and effort needed to develop coherent, integrated storylines, instead of developing their own storylines, many studies use storylines from existing scenario studies to conduct detailed analyses of the impacts of these different scenarios on for instance the distribution of specific species.

In contrast, *intervention scenarios* focus on informing policy design and implementation by evaluating alternative policy or management options through target seeking or policy screening analyses (IPBES, 2016). In these studies, different management or land-use options are often referred to as "scenarios". These scenarios are, however, conceptually and qualitatively distinct from the integrated scenario storylines developed in exploratory scenario studies, in which rich scenario narratives with variability across multiple issues, rather than variation in single policy options, are explored. To date, assessments at global, regional and national scales have mostly used exploratory scenarios, while intervention scenarios have been mostly applied to decision-making at national and local scales (IPBES, 2016). Finally, *policy evaluation scenarios* are mostly employed in retrospective assessments of the extent to which outcomes actually achieved by an implemented policy match those expected based on modelled projections, thereby informing policy review. These scenarios focus on evaluating the outcomes of different policies or actions that have been undertaken.

Another important distinction is between *participatory scenarios*, which are developed with substantial input from stakeholders, and non-participatory or *expert-driven* scenarios. Participatory scenarios allow for the integration of stakeholder views on key drivers of future developments and enhance the relevance and acceptance of scenario findings (Kok *et al.*, 2007). Participatory scenarios can also provide an important avenue for integrating Indigenous and Local Knowledge (ILK) with scientific knowledge, which can fill important information gaps and contribute to the successful application of scenarios and models to policy design and implementation (IPBES, 2016). While participatory scenarios are usually more relevant and credible to stakeholders and policymakers, they are also often more costly and complicated to execute (Biggs *et al.*, 2007).

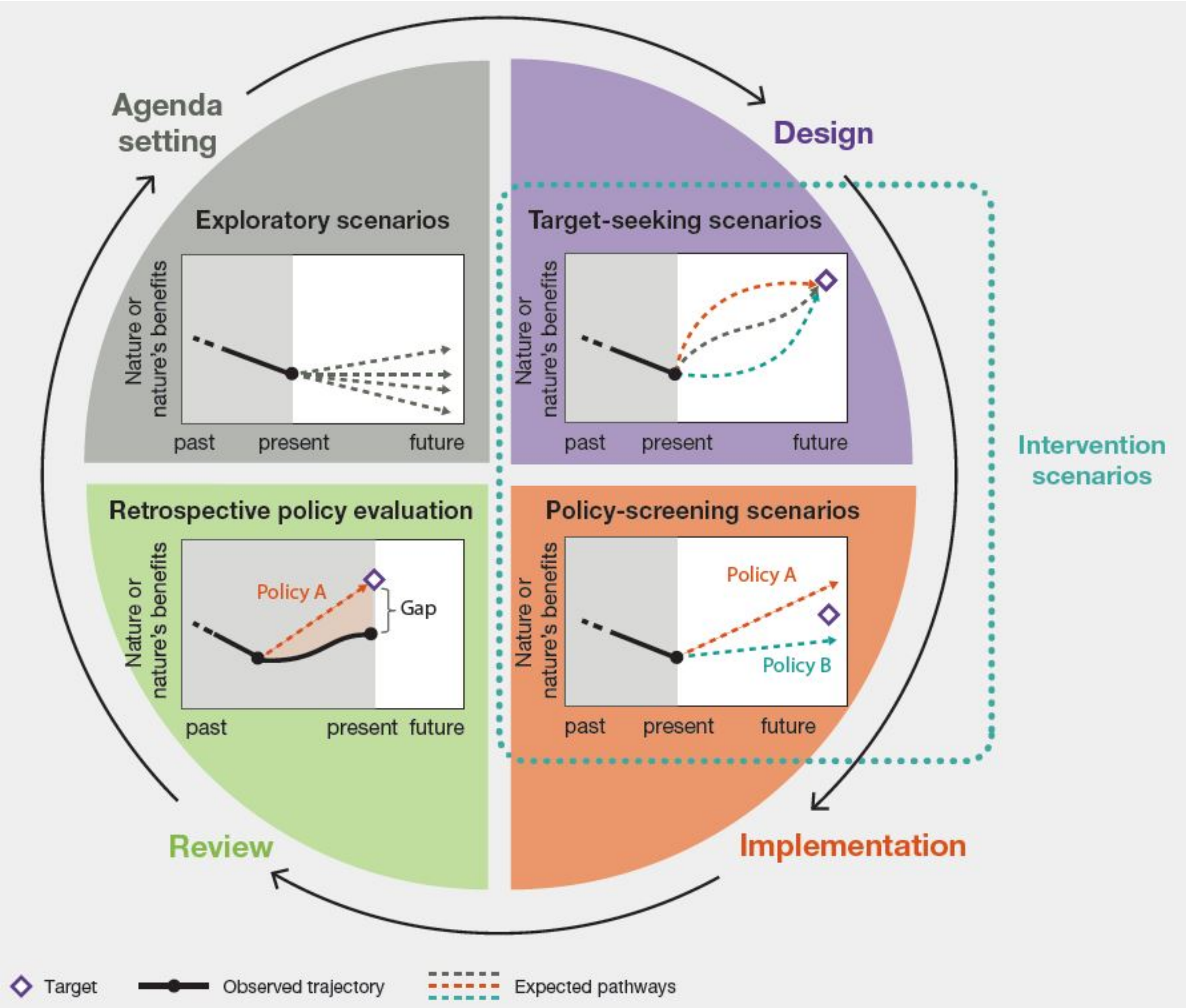


Figure 5.1: Roles played by different types of scenarios corresponding to the major phases of the policy cycle. Types of scenarios are illustrated by graphs of changes in nature and nature's benefits over time. The four major phases of the policy cycle are indicated by the labels and black arrows outside the coloured quarters of the circle. In "exploratory scenarios", the dashed lines represent different plausible futures, often based on storylines. In "target-seeking scenarios" (also known as "normative scenarios"), the diamond represents an agreed-upon future target and the coloured dashed lines indicate scenarios that provide alternative pathways for reaching this target. In "policy-screening scenarios" (also known as "ex-ante scenarios"), the dashed lines represent various policy options under consideration. In "retrospective policy evaluation" (also known as "ex-post evaluation"), the observed trajectory of a policy implemented in the past (solid black line) is compared to scenarios that would have achieved the intended target (dashed line). Source: IPBES (2016).

Models are often used as part of scenario analyses. Scenario storylines typically focus on possible futures for drivers of change or policy interventions (e.g., population growth, economic growth), and a variety of models are then used to translate these into projected changes in key drivers of environmental change (e.g., land-use change, fishing pressure), consequences for biodiversity and ecosystem function (e.g., species extinctions, habitat loss), NCP (e.g., control of water flow and quality, cultural values), and human well-being (e.g., access to food, health, spiritual satisfaction) (IPBES, 2016). Models are qualitative or quantitative descriptions of key components of a system and the relationships between those components, and are directly dependent on data and knowledge for their construction and testing. As such, models tend to draw on past observations and patterns, which can limit their utility in exploring futures that entail novel interactions and feedbacks between nature and society (IPBES, 2016).

As the number of scenario studies focusing on environmental futures and their implications for human societies has grown, there has been recognition that the storylines developed in different studies often have similarities. For example, the Millennium Ecosystem Assessment (MA, 2005) and the Global Environmental Outlook 4 (UNEP, 2007) each developed four different global scenarios, some of which explore similar trajectories for the future of nature and society. For instance the Millennium Ecosystem Assessment "Order from Strength" scenario and the GEO-4 "Security First" scenario both explore futures where the rich and poor have become highly fragmented and security and national sovereignty trump collective action around environmental issues. Such similarities between the storylines from different scenario studies have been used to identify a set of general *scenario archetypes* that can be used to facilitate synthesis and comparison across studies (Hunt *et al.*, 2012; Wardropper, 2016). Within the global environmental change field, the most widely used archetypes for comparing scenario studies are based on the Global Scenarios Group work (Gallopín *et al.*, 1997) which identified six archetypes: *Policy Reform, Market Forces, Breakdown, Fortress World, Eco-Communalism* and *New Sustainability Paradigm*.

5.1.2. What lies ahead?

This chapter presents an assessment of scenario studies of the African region that are relevant to understanding the future of nature-society interactions and their consequences for biodiversity, NCP and quality of life on the continent. This assessment was carried out in two parts. The first part (Section 5.2) presents a systematic review of the published literature to provide an overview of the types of scenario studies that have been undertaken in Africa, and the extent to which they have addressed priority issues relevant to Africa (see Chapter 1). This section further highlights the scales and subregions of Africa that have been considered, the scenario development approaches used (participatory, modelling, inclusion of indigenous and local knowledge) as well as the authorship of these studies as an indicator of scenario development capacity within Africa.

The second part of the assessment (Sections 5.3–5.7) focuses on a subset of key studies identified in the review that address the future of biodiversity and NCP across the African continent, supplemented where possible by findings from the wider set of scenario studies identified in the systematic review. In order to compare and synthesize the findings across all the different studies and scenario storylines, we classified the studies into the Global Scenarios Group scenario archetypes as described in Section 5.3. The remainder of the chapter presents the assessment of possible futures of key drivers of change (Section 5.4), the consequences for biodiversity, NCP (Section 5.5), and human well-being (Section 5.6), as well as the implications for achieving key development targets and addressing priority development issues (Section 5.7) across Africa in the 21st century, in terms of the five broad scenario archetypes the studies represent. Finally, we conclude the chapter by discussing potential trade-offs, thresholds, cross-scale linkages and tele-couplings across different potential trajectories of social-ecological change (Section 5.8).

5.2. Systematic review of scenario studies in Africa

To assess what existing scenario studies suggest about the future trajectories of nature-society interactions, biodiversity, NCP and good quality of life across Africa, a comprehensive systematic review was conducted to identify relevant studies. This section presents the approach and key findings of the review.

5.2.1. Approach

Several complementary approaches were used to identify relevant scenario studies. First, a literature search was performed in the Web of Science database with the keywords: "Africa* AND scenario* AND (ecosystem OR biodiversity)"[6]. Only papers published since the Millennium Ecosystem Assessment (MA), i.e., between 2005 and 2016, were included. To ensure that no key studies were missed, particularly those published in the grey literature (such as reports), the same search was repeated in Google Scholar. A further search was based on the purposive sampling of IPBES experts to identify other important documents. Finally, the French literature was searched for studies and reports published in French. Translations of the search terms were used in the French version of Google Scholar (scholar.google.fr). All papers and reports thus identified were scanned for relevance. If the study only mentioned scenarios without having analysed or explored any scenarios, or if the paper or reports did not include African study sites, the study was excluded.

In total, these approaches identified 355 relevant papers and reports, published between 2005 and 2016 (See Supplement 5.1[7]). These studies were then reviewed in some detail: First, the papers and reports were assessed to identify whether they represented exploratory, target-seeking, policy-screening or retrospective policy evaluation studies. Second, each study was categorised based on whether new, integrated scenario storylines were developed (which we termed a *type 1* scenario study), whether existing scenarios (such as IPCC SRES, Nakicenovic *et al.*, 2000) were used to explore or model specific variables (e.g., species distribution) into the future (termed *type 2* studies), or whether parameter changes and their impacts were explored (e.g., different sizes of a protected area—i.e., different "scenarios"—were modelled to assess conservation impact for a certain set of species; termed *type 3* studies). The literature identified in the systematic review included all three types of studies, and some studies represented a combination of different types.

Other information captured during the review included information on the location of the study site, and the scale of the study (local, national, regional or global). The review also noted which key issues the study addressed (e.g., food, water, energy, invasive species, or livelihoods and poverty) that pertain to the key issues identified in the IPBES Scoping Report, including the food-energy-water-livelihood nexus, land degradation, invasive species and zoonotic diseases. Other issues such as climate, urbanisation and gender were captured due to their importance as factors of change and development on the African continent. It was also noted whether the study addressed issues around thresholds or trade-offs which are key to understanding interactions between nature and society.

The review further captured the approach to scenario analysis (participatory, modelling, or including indigenous local knowledge). To understand what kind of models were used, the 301 (out of 320)

[6] These search terms were chosen to limit results to studies that specifically mention scenarios, and anything to do with biodiversity or ecosystems, including ecosystem services. An exploratory search including additional terms such as "nature", "contributions", "well-being" or specific ecosystem service descriptors (e.g., "food") resulted in a much larger set of studies, most of which were not relevant to this assessment. We thus chose to work with the narrower set of search terms.

[7] Supplement 5.1 can be retrieved from https://www.ipbes.net/africa-ra-ch5-supplement-51

modelling studies published in English were classified into three broad classes, namely correlative, process-based and expert-based models (IPBES, 2016). To assess the capacity for undertaking scenario studies in Africa, VOSviewer 1.6.5 software was used to conduct a bibliometric analysis of authorship on the subset of studies that appear in the Web of Science database (n=322).

5.2.2. Key findings

The 355 identified studies showed a variety of patterns in terms of scenario types, geographic area, scale and themes covered, as well as scenario development approach and authorship.

5.2.2.1. Types of scenario studies

In terms of the IPBES typology of scenario research, the vast majority of reviewed studies were exploratory (80%). A fair share of studies were policy screening (17%), but only 6% were target-seeking, and 1% represented retrospective evaluations of a policy (so-called “backcasting” studies) (Figure 5.1). In terms of our type 1, 2 and 3 classification of scenario studies, only 14% of the studies developed their own scenario storylines (type 1 studies). This translates to only 49 scenario exercises that constructed their own scenario narratives for Africa, or parts thereof, since 2005. In terms of exploratory studies, the majority (46% of studies reviewed) based their analyses on existing scenarios (type 2 studies), rather than developing their own storylines. The IPCC climate scenarios were by far the most commonly used scenarios in these type 2 studies. Finally, almost half the reviewed literature (46%) was made up of type 3 studies, which explore the impacts of specific management-related parameter changes. These kinds of studies use the term “scenario” more loosely, often referring to different management options or changes in model parameters as scenarios. Note that some studies represented a combination of different types and approaches, including for instance IPCC-based type 2 studies that also varied management parameters (such as land-use).

5.2.2.2. Scale and geographic area

The majority of scenario studies were conducted in southern Africa (37%), and by far the majority of studies were local in scale (46%) (Figure 5.2). In contrast, 18% of the studies were part of or based on a global scenario study, while 8% covered all of Africa. A similar predominance of scenario studies focusing on southern Africa (and particularly South Africa) has previously been found in the French literature (FRB, 2013). This pattern of prevalence of studies in southern and eastern Africa is not unique to scenario studies, and may be explained by the relative dominance of these subregions in biodiversity research more generally within the African continent (Wilson *et al.*, 2016; Proença *et al.*, 2017).

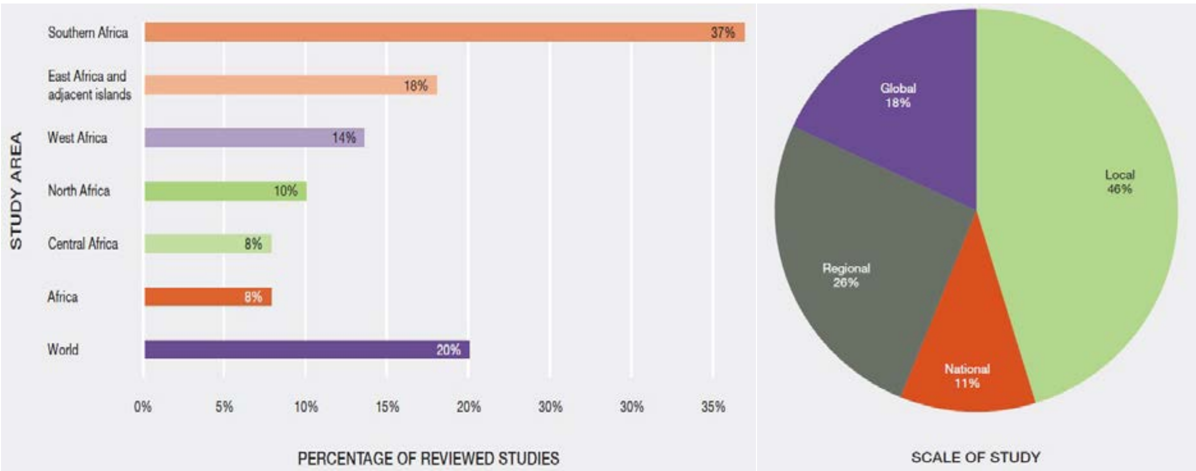


Figure 5.2: Percentage of studies in the systematic review covering different a) IPBES regions and subregions, and b) geographic scales. Note that some studies spanned more than one subregion and totals exceed 100%.

5.2.2.3. Key issues addressed

Of the key issues addressed in the studies, climate featured in 60% of the studies (Figure 5.3). These results are supported by a recent global review of French studies on biodiversity scenarios, which identified climate as a driver of change in 60% of the studies considered (FRB, 2013). Other commonly occurring themes in our assessment were biodiversity and ecosystem services, with some studies focussing on specific species or ecosystem services like food production. Gender was only specifically mentioned in five of the 355 studies.

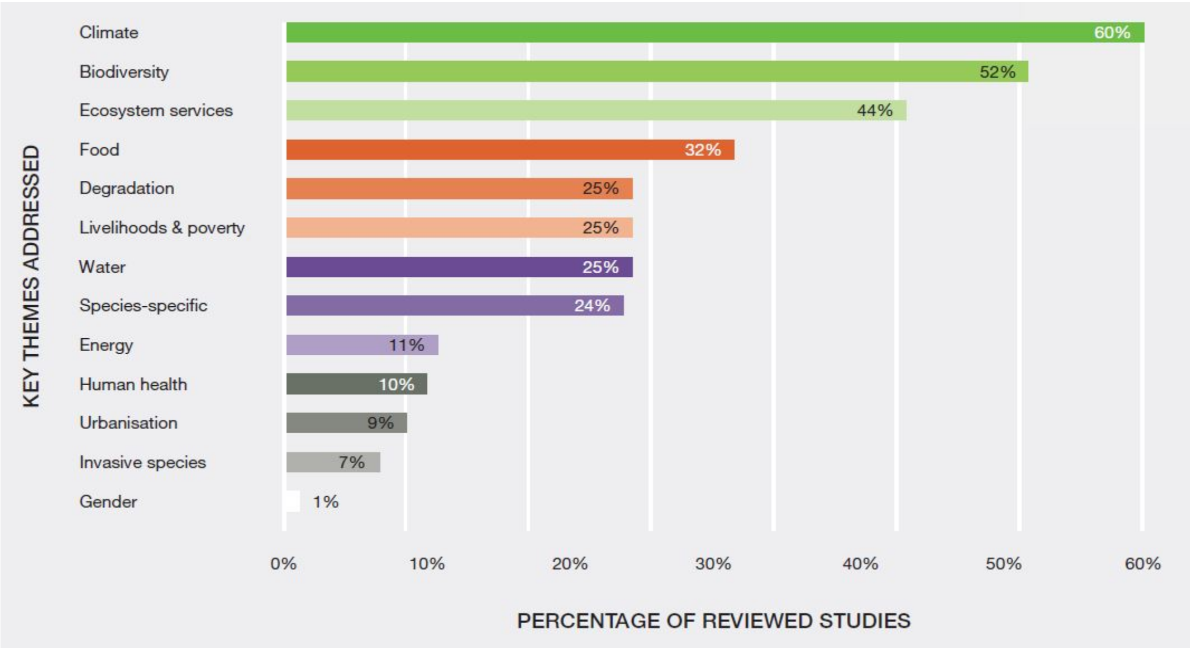


Figure 5.3: Percentage of scenario studies that addressed the priority issues identified in the IPBES scoping report. Note that many studies address more than one theme.

An analysis of the co-occurrence of issues indicated that climate studies were associated with biodiversity (with many studies adopting a species-specific focus), ecosystem services, degradation and water. Ecosystem service studies were closely linked to water and food production. Issues rarely considered in combination with other issues include energy, gender, urbanisation, invasive species and human health. These issues are recognised as areas of concern in the IPBES conceptual framework, with important relationships highlighted in other chapters in this assessment (including Chapter 1). There is significant potential for future studies to focus on the relationships between these issues using scenario analysis as a tool to provide a greater understanding of their potential interactions.

5.2.2.4. Participatory and modelling approaches

Of the 355 studies, only 12% used a participatory approach, where a study was classified as participatory if it involved not only the authors of the study but other stakeholders as well. Most of these participatory studies also included a modelling element, and overall, 90% of the reviewed studies made use of models.

In the 301 modelling studies that were assessed, the majority used correlative models (48%), followed by process-based models (29%), and expert-based models (8%). The main advantage of correlative models is that relationships between system elements are derived inductively from empirical observations, whereas process-based models require an understanding of ecological processes before relationships are deduced, quantified or explicitly modelled. A few studies (7%) mixed multiple modelling approaches when combinations of issues were addressed. Studies using integrated or hybrid models (7%) were often associated with global or regional scale analyses, possibly because these models have larger data and computing requirements.

5.2.2.5. Inclusion of Indigenous and Local Knowledge (ILK)

There is clearly a dearth of studies which truly integrate ILK into scenario development in the African context. In total, only 11 of the 355 studies included some aspect of ILK, either in the development of scenarios or in the analysis of the impacts of different pathways. Most of these studies (10 out of 11) were participatory, but only two incorporated ILK in the scenario development process in a thorough manner (see Box 5.1 and Dougill *et al.*, 2010). In the other studies, none explicitly dealt with ILK in the modelling aspects, nor did the participants mention ILK as a driver of change in the narratives that were developed. Instead, the inclusion of ILK involved little more than passing mention of the knowledge of stakeholders that participated in scenario modelling.

5.2.2.6. Capacity to undertake scenario studies

Overall, 56% of the reviewed studies involved African authors (from a total of 28 African countries), but only 19% of the studies involved *only* authors affiliated with African institutions. Most of the studies assessed included authors based in the USA (n=94), closely followed by South Africa (n=92) (Fig 5.4). The only other African country represented in the ‘top ten’ countries of authorship is Kenya, in 8th position (n=23); the next African country, Ethiopia, is in 17th position with authors involved in 10 of the studies assessed (or 3%). In total, European authors contributed to 195 publications, which makes Europe the most prolific continent in terms of authorship of the studies assessed. In terms of institutional affiliation, the analysis shows a concentration of scenario work in South African institutions: the six most productive institutions in terms of author affiliation are all South African, with Stellenbosch University and the University of Cape Town the only institutions involved in more than 20 publications (23 and 21 publications, respectively).

Box 5 1 **Incorporating ILK into scenarios: Forest landscapes in south-eastern Cameroon. Source: Image of pygmy village, Dja national park, Cameroon from Shutterstock.**

The study by Sandker *et al.* (2009) illustrates how ILK can be more deeply integrated into the scenario development process. The study aimed to explore the trade-offs between conservation and development in south-eastern Cameroon, where illegal hunting is regarded as the greatest challenge to conservation. The study involved a participatory scenario process that engaged local participants. Data from interviews with indigenous communities were incorporated into participatory modelling and visioning workshops that involved representatives of a diverse set of stakeholders.

The major drivers of change underlying the different scenarios were informed by each of the stakeholder's knowledge of the landscape and its interactions. The resulting scenarios explored the effects of different Integrated Conservation Development Projects (ICDPs) strategies through simulation models by varying the degree of focus on anti-poaching activities, anticorruption measures and direct development investments, and by varying the overall budget for such activities (i.e., a type 3 scenario exercise). The scenarios focused specifically on poverty and biodiversity outcomes, and were used to identify key issues for future modelling. In this way ILK was indirectly incorporated in the major drivers and interventions considered in the scenarios exercise.

Although this study is one of the best examples of how ILK has been integrated into a scenario development process, the study could have been more explicit about how ILK was included in the scenarios and visioning workshops. The scenarios explored development outcomes associated with different management strategies, but could also possibly have been more explicit about the future of ILK itself in the studied landscapes.

However, collaborations between South Africa and other African countries is low: only 2 collaborative studies were found. With the exception of South Africa and, to some extent, Kenya, these findings indicate a clear lack of African-based capacity in the study of biodiversity and ecosystem service-related scenarios. Furthermore, while expertise exists in countries like South Africa, it is not being sufficiently leveraged towards building capacity across the rest of the continent (see Wilson *et al.* (2016) for similar conclusions in the field of conservation research more broadly).

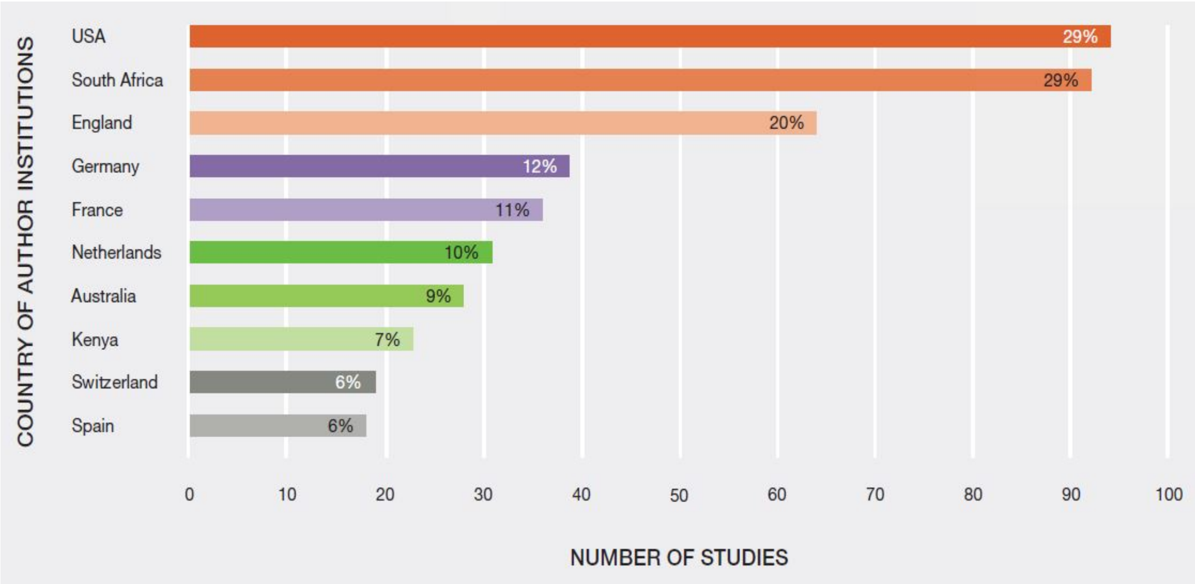


Figure 5.4: Top ten countries in which the authors of the scenario studies included in the assessment were based, ranked by the number of studies that included at least one author based at an institution in a given country. Percentages indicate what proportion of the total studies the numbers represent (from Web of Science entries only, n = 322).

5.3. Classifying scenario studies into archetypes

The 355 studies identified in the systematic review outline a very large number of different potential futures for Africa, across a wide range of geographical scales (Figure 5.2). Each study typically explores three or more different future scenarios, and each has its own particular assumptions. In order to synthesize and assess what all these different scenarios suggest about the future trajectory of key drivers, biodiversity, NCP, human well-being outcomes and the implications for key policy targets in Africa, we focused on 26 scenario storylines taken from a subset of six core studies that were identified as particularly relevant to our assessment, and classified these storylines into the Global Scenarios Group (GSG) archetypes. The six selected core studies include the WWF Ecological Futures scenarios (WWF-AfDB, 2015) that were specifically developed for Africa and also used in the GEO-6 regional assessment (UNEP, 2016), the GEO-4 global assessment (UNEP, 2007), the Millennium Ecosystem Assessment Scenarios (MA, 2005), and to a lesser extent, the IPCC climate change scenarios (Nakicenovic *et al.*, 2000; Moss *et al.*, 2008, 2010; Kriegler *et al.*, 2010; van Vuuren *et al.*, 2012). These six studies were selected as they constitute type 1 studies that have developed their own integrated storylines, specifically address the future of biodiversity and NCP, cover the entire African continent, have been used by a substantial number of type 2 scenario studies to explore more detailed impacts and consequences of the storylines, and most have been previously classified into the GSG archetypes (van Vuuren *et al.*, 2012, 2014a). Two of the older scenario studies (Nakicenovic *et al.*, 2000; UNEP, 2007) were included as several recent papers identified in the systematic review used these studies. Given the lag in publishing times, even though the WWF/GEO6 scenarios (WWF-AfDB, 2015; UNEP, 2016) were specifically developed for Africa and are probably the most relevant to this assessment, there have been few detailed analyses of the implications of these storylines in either the original or follow-on type 2 studies to date.

Table 5.1 gives a summary of the key differences between the five GSG archetypes covered by the storylines we assessed, as described at the global level, and Box 5.2 provides a brief description of each archetype. Sections 5.4–5.8 provide an assessment of these archetypes specifically for Africa. To facilitate clarity and highlight the key features relevant to the African context, we renamed the GSG New Sustainability Paradigm archetype to *Regional Sustainability*, and the GSG Eco-Communalism archetype to *Local Sustainability*. The GSG *Breakdown* archetype was excluded, as none of the major studies we assessed had scenarios corresponding to this archetype, which represents an extremely undesirable future. Table 5.2 provides a classification of the 26 storylines from the six core studies we assessed into the five GSG archetypes.

When classifying scenarios into archetypes, it is important to keep in mind that not all scenario storylines fit neatly into a particular archetype, and some scenarios may have elements of more than one archetype, or occasionally represent a completely different storyline not covered by the archetypes. An archetype approach can also mask differences among scenarios by emphasising shared elements rather than addressing differences that arise from different assumptions, methods, data and goals. While taking note of these limitations, for the purpose of this assessment an archetype approach was deemed the most effective and practical way to assess and synthesize the wide diversity of potential future trajectories of change in Africa based on the key studies identified in the systematic review.

Table 5.1: Key characteristics and assumptions of the different Global Scenarios Group (GSG) archetypes, at the global level. As highlighted in the assessment presented in this chapter (sections 5.4–5.8), trends within Africa may differ substantially from the global trends. Note that *Regional Sustainability* and *Local Sustainability* correspond to the Global Scenarios Group (GSG) archetypes New Sustainability Paradigm and Eco-Communalism respectively. Source: based on van Vuuren *et al.* (2010).

GSG ARCHETYPE CATEGORY	FORTRESS WORLD	MARKET FORCES	POLICY REFORM	LOCAL SUSTAINABILITY	REGIONAL SUSTAINABILITY
MAIN OBJECTIVES	Security	Economic growth	Various goals	Local sustainability	Regional & global sustainability
Global population growth	High	Low	Low	Medium	Low
Global technology development	Slow	Rapid	Rapid	Ranging from slow to rapid	Ranging from mid to rapid
Global economic development	Slow	Very rapid	Rapid	Ranging from mid to rapid medium	Ranging from slow to rapid
Trade	Trade barriers	Globalization	Globalization	Trade barriers	Globalization
Policies and institutions	Strong national governments	Policies create open markets	Policies reduce market failures	Local steering; local actors	Strong global governance
Environmental management	Reactive	Reactive	Both reactive and proactive	Proactive	Proactive

The following sections provide an assessment of the future trajectory of key drivers (Section 5.4), biodiversity and ecosystem services (Section 5.5), human well-being outcomes (Section 5.6) and policy implications (Section 5.7) under each of the five archetypes, based on an assessment and comparison of the trends identified in each of the six core studies. Where possible, we supplemented the findings in the six core scenario reports with those from the wider set of scenario studies identified in the systematic review, particularly those of type 2 studies that have used one or more of storylines developed by the core studies. Many of these studies were conducted at local and regional levels and give insight into potential regional variations in the way the different archetypes could play out across the African continent. Among the supplementary studies included in the following sections, two noteworthy regional studies stand out in terms of their scope and/or level of participatory engagement: one that developed integrated type 1 scenarios for eastern Africa (Burundi, Ethiopia, Kenya, Rwanda, Tanzania, Uganda) (Vervoort *et al.*, 2013) and a second that developed scenarios for the continent as a whole (Cilliers *et al.*, 2011).

Box 5 2 Overview of the scenario archetypes used to categorise the scenarios surveyed in this chapter.

The Market Forces archetype emphasises the role of markets to deliver economic, social and environmental benefits through free trade and the commoditization of nature (UNEP, 2007). In cases such as forests, the [re-]valuation of ecosystems as economic amenities slows habitat loss and environmental degradation (Nakicenovic *et al.*, 2000). However, demand for resources such as water increases as a consequence of both more people overall, and a greater demand for water for agricultural, industrial, urban and domestic uses (UNEP, 2002). The commercial exploitation of natural resources comes at the expense of local livelihoods, as well as indigenous and local knowledge, as communities are increasingly marginalised, fuelling tensions as resources degrade or become inaccessible (UNEP, 2016). In many cases, exploitation of natural resources to satisfy trade demand leads to over-harvesting and habitat fragmentation, which is exacerbated by weak centralised governance, poor environmental enforcement (WWF-AfDB, 2015; UNEP, 2016), and illegal/unsustainable harvesting from protected areas in the absence of alternative livelihood options (UNEP, 2016).

Policy Reform balances strong economic growth with minimising environmental consequences through a holistic approach to governance (UNEP, 2007). Owing to low levels of population growth overall globally, habitat loss is moderate (MA, 2000) and protected areas expand due to increased social and political recognition of the value of healthy ecosystems. However, beyond these 'conservation islands', biodiversity declines (UNEP, 2016). Agricultural intensification prioritises the green economy, which benefits marine systems as extraction eases (UNEP, 2016). This is to the detriment of artisanal fishers as their local scales of operation prevent their participation in the marine economy that remains (UNEP, 2016). Export-driven growth constrains economic diversification, and dependency on environmental resources associated with agriculture and extractive commodities exacerbates environmental degradation in the long-term (WWF-AfDB, 2015).

The Fortress World archetype prioritises national sovereignty, self-reliance and security over other values, fragmenting international action around environmental issues (Nakicenovic *et al.*, 2000; UNEP, 2007). Expansive agriculture drives habitat loss, soil erosion and water pollution (Nakicenovic *et al.*, 2000), and crop yields are slow to improve (MA, 2000). Fortress World predicts the largest relative habitat loss by 2050, undermining provisioning services (MA, 2005), and water stress increases dramatically, with Africa being especially vulnerable (UNEP, 2007). The intrinsic vulnerabilities of already fragmented habitats are worsened through increasing poverty levels and the over-exploitation of ecosystems (MA, 2005). A Fortress World future raises significant challenges for both mitigation and adaptation to climate change (O'Neill *et al.*, 2014).

In the Regional Sustainability archetype, environmental consciousness is heightened, with technological innovation driving global and regional solutions to sustainability issues (Nakicenovic *et al.*, 2000). Sustainable land management and strong incentives for low impact agriculture (Nakicenovic *et al.*, 2000), combined with increased crop yields (MA, 2005), leads to less habitat transformation. More effective governance allows for more effective environmental regulation, increasing protected area function and coverage, and allowing for improved transboundary environmental cooperation (UNEP, 2016). Conservation efforts are directed at sustainable use and maintenance of ecosystem services, rather than species protection (UNEP, 2007). Although the rate of land-cover change remains high – with agriculture and climate change significant drivers of species loss (UNEP, 2007) – the broader trend is towards land-use changes that 'green' the landscape (Nakicenovic *et al.*, 2000).

The Local Sustainability archetype prioritises environmental protection, social equality and human welfare (Nakicenovic *et al.*, 2000), but action towards sustainability is largely taken only at local levels (UNEP, 2016). Local agriculture operates through participatory-decision making and cooperative schemes (WWF-AfDB, 2015), which, when combined with low population growth, and the eventual adoption of sustainable practices, drives lower rates of habitat loss (MA, 2005). While local sustainable agriculture ensures 'sustainability brightspots', beyond these areas, degradation continues and habitats are fragmented as the uncoordinated nature of local agricultural choices undermine regional ecological integrity in the longer-term (WWF-AfDB, 2015). This archetype has the highest likelihood for retention of ILK as a result of its particular focus on local scales.

Table 5.2: Classification of the six core scenario studies assessed in this chapter into the Global Scenarios Group (GSG) archetypes. The names listed in the rows are the names of the different scenarios (e.g., Helping Hands, Going Global, Good Neighbours, All in Together) within each scenario study (e.g., WWF/GEO6). Where cells remain empty, the scenario study does not have an equivalent scenario archetype. Sources: classification based on van Vuuren *et al.* (2012, 2014a).

SCENARIO ARCHETYPE	FORTRESS WORLD	MARKET FORCES	POLICY REFORM	LOCAL SUSTAINABILITY	REGIONAL SUSTAINABILITY
WWF/GEO6		Helping Hands	Going Global	All in Together	Good Neighbours
GEO4	Security First	Markets First	Policy First		Sustainability First
MA	Order from Strength		Global Orchestration	Adapting Mosaic	TechnoGarden
IPCC SRES	A2	A1 (A1FI)	E1	B2 (A1B)	B1 (A1T)
IPCC RCP	8,5	8,5	2,6	6	4,5
IPCC SSP	SSP3(4)	SSP5		SSP2	SSP1

5.4. Drivers of change

Drivers of change refer to all those external factors that affect nature, anthropogenic assets, nature's contributions to people, and good quality of life (Díaz *et al.*, 2015). The IPBES conceptual framework indicates that drivers of change influence the relationships between people and nature through, a) institutions and governance systems and other indirect drivers and b) direct drivers. A detailed list of these drivers has been presented in Chapter 4, which explicitly focuses on all the major current direct and indirect drivers impacting Africa's biodiversity and ecosystems. Scenarios provide a means to explore the future impacts of these drivers based on various assumptions that shape their direction and rate of change.

This section explores the future trajectory of key drivers impacting the future of biodiversity, NCP and good quality of life in Africa under each of the five scenario archetypes presented in section 5.3, drawing primarily on the core scenario studies as categorised in Table 5.2. These studies used an exploratory approach to scenario development to explore different potential development pathways associated with different combinations of drivers and assumptions. In this section, we focus on potential future variation in the following key drivers highlighted in Chapter 4 and explored across all core scenario studies: Population, urbanisation, consumption and natural resource use, global trade and resource demand, and climate change. Many of these studies do not describe these drivers in quantitative detail, nor do they address their consequences for all of the major indirect and direct drivers highlighted in Chapter 4 (e.g., habitat change, chemical pollution or invasive species). Despite this, the detail provided in the qualitative scenario narratives provide a means to explore a range of future possibilities (Enfors *et al.*, 2008) and highlight knowledge gaps in the context of Africa. A summary of the findings of each of the core studies is presented in Table 5.3.

Table 5.3: Summary of the trajectories of key drivers in Africa under the different archetypes. Arrows indicate an increase (↗), decrease (↘), or no change (→) in drivers under each scenario type. Within a cell, arrows represent the main scenario reports in the following order: IPCC; MA; GEO4; WWF/GEO6. If a report does not cover an archetype, this is symbolised by '0', whilst if a report does not explicitly address a specific element, it is indicated by an 'X'. The colour of the cell indicates the overall trend across the reports, where orange indicates an overall increase in driver pressure, purple indicates contradictory trends, and no colour indicates no overall change.

	FORTRESS WORLD				MARKET FORCES				POLICY REFORM				LOCAL SUSTAINABILITY				REGIONAL SUSTAINABILITY			
DRIVERS	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF
Population	↗	↗	↗	O	↗	O	↗	↗	O	↗	↗	↗	↗	↗	O	↗	↗	↗	↗	↗
Urbanisation	X	↗	↗	O	X	O	↗	↗	O	↗	↗	↗	X	↗	O	↗	X	↗	↗	↗
Consumption and natural resource use	↗	↗	↗	O	↗	O	↗	↗	O	↗	↗	↗	→	↗	O	↗	↗	↗	↗	↗
Regional and global resource demand	→	→	↘	O	↗	O	↗	↗	O	↗	↗	↗	→	↘	O	↗	↘	↗	X	↗
Climate change	↗	↗	↗	O	↗	O	↗	↗	O	↗	↗	↗	↘	↗	O	↗	→	↘	↗	↗

↗ Increase ↘ Decrease → No change O Not covered X Not addressed

Overall increase in driver pressure; Contradictory trends; No overall change

5.4.1. Population

Global trends in population growth indicate a growing but declining rate of growth towards 2100. However, Africa is recognised as having the highest rate of growth among the world regions, which is approximately twice the global average. Africa's population is projected to grow by 270% between 2015 and 2100 (UN, 2015; Boke-Olén *et al.*, 2016) and is expected to double by 2050, to approximately 2.5 billion people, having reached 1 billion in 2009. These recent revisions indicate a substantial increase from previous estimates for African population reflected under the Millennium Ecosystem Assessment or IPCC scenarios (UN, 2015). Yet these revised estimates have not been included in the core scenario studies. For this assessment, estimates of population size in 2050 per archetype were extracted from the GEO4 report (UNEP, 2007) which draws results from the United Nations Population Division edition of 2007 (UNDP, 2007). Although these estimates are currently outdated, the trends in the archetypes remain relevant into the future.

For Africa, the highest population of 2.3 billion people by 2050 occurs under the Fortress World archetype. Intermediate population projections of 2 billion and 1.7 billion people occur under the Market Forces and Policy Reform archetypes respectively. The lowest projection of 1.4 billion people occurs under the Regional Sustainability archetype. The Local Sustainability archetype is not represented by the GEO4 assessment (UNEP, 2007) but based on previous projections is also meant to have the lowest population growth rates (MA, 2005).

All scenarios highlight the impacts of population growth on biodiversity and ecosystems presenting a major driver of environmental change across all scenario archetypes (MA, 2005; IPCC, 2007; WWF-AfDB, 2015; UNEP, 2016).

5.4.2. Urbanisation

Urbanisation across Africa is expected to increase under all scenario archetypes presenting both opportunities and challenges for environmental management. Current trends indicate a 590% increase by 2030 in urbanisation compared to 2000 (Seto *et al.*, 2012). Several assumptions regarding economic growth, governance structures and climate under the different archetypes have a strong influence on whether urbanisation is centralised around few economic and industrial economies or decentralised across expanding rural economies (WWF-AfDB, 2015). These factors also strongly contribute to rural-urban patterns of migration and re-migration (Lambin *et al.*, 2014).

Under the majority of the archetypes namely, *Policy Reform*, *Regional Sustainability* and *Market Forces*, centralised urbanisation strategies, driven by economic development and population growth, occur. Under *Policy Reform*, economic growth in some cities or countries and conflict and rural poverty in others, are the main factors driving migration (MA, 2005). Under *Market Forces*, urbanisation is likely to manifest as informal and unserviced settlements (WWF-AfDB, 2015), clustered around economic hubs or resource-rich areas with poor infrastructure development. In contrast, under the *Local Sustainability* archetype, a densification of rural African communities is expected at first. These large rural populations are likely to be limited by economic options, and increasingly rely on the natural resources to sustain their well-being (Sandker *et al.*, 2012). Sustained overexploitation of local food supplies eventually acts as a driver of migration out of rural areas where men and young people leave for the cities, leaving behind elderly woman and children (WWF-AfDB, 2015). This reduced pressure may provide an opportunity for the replenishment of natural resources (Sandker *et al.*, 2012).

Under all archetypes, urbanisation has large impacts on surrounding areas as the demand for, and pressure on, natural resources and ecosystem services increases, posing significant ecological risks. These include habitat loss, fragmentation, deforestation, loss of agricultural land, and increased demand for bushmeat and medicinal plants (MA, 2005; O'Farrell *et al.*, 2012; Seto *et al.*, 2012; Herslund *et al.*, 2016; IPCC, 2014). These impacts are exacerbated if there is insufficient provision of adequate basic services. For example, lack of electricity means that charcoal is used as a major energy source in urban areas in Tanzania and other African cities (Swetnam *et al.*, 2011; Woollen *et al.*, 2016), contributing to deforestation and habitat loss.

5.4.3. Consumption and natural resource use

Future consumption patterns of natural resources across Africa are expected to change as a result of rapid population growth, increased trade, and an expanding middle class (Alcamo *et al.*, 2005). However, large regional differences are expected, as well as substantial differences depending on which development pathways are followed. Differences in institutions and governance systems, as well as differences in technological advances and strategic infrastructure investment in agriculture, manufacturing and other key sectors are likely to have marked impacts on the demand for food, clean water, energy, fibre and marine and freshwater fisheries, as well as habitat conversion (e.g., degradation or restoration of land and aquatic habitats), climate change and species introductions (MA, 2005).

Africa currently exceeds its biocapacity, with only 33% of the countries within acceptable limits (GEF, 2016). Rates of consumption and natural resource use are expected to increase further under all archetypes except *Fortress World*, where consumption patterns are expected to remain steady or decrease due to poor economic growth (MA, 2005). Under this archetype, however, natural resource use remains high to provide sufficient food for dense rural communities. Natural resources are expected to remain the primary trade across the continent, sustaining current pressures on biodiversity and ecosystem services. The potential for further increases in environmental pressure is confirmed by recent modelling studies where potential increases in cropland range between 19%–120% across Africa, but could also decrease by ~27% under certain scenarios (Schmitz *et al.*, 2014). Energy use per capita in Africa is expected to remain the lowest in the world under all archetypes (UNEP, 2007).

Box 5 3 **The future of food security, environments and livelihoods in Eastern Africa: four socio-economic scenarios. Sources: graphic adapted from Vervoort *et al.* (2013); Cartoon representation of the scenarios by artist Mauvine Were.**

REGIONAL INTEGRATION

PROACTIVE GOVERNANCE ↔ **REACTIVE GOVERNANCE**

Industrious Ants

Wide range of benefits for food security, environments and livelihoods

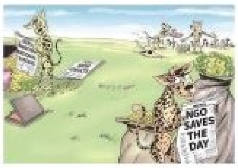
- Difficult international relations
- Costly battle with corruption
- Challenges of being competitive with crops and products aimed at domestic markets

Herd of Zebra

Region reaches out to international markets – economic boom

- Trade-off with food security and environment, not sustainable economically
- Dependency on service and industrial markets
- New vehicles for corruption sap effectiveness

Lone Leopards



Visionary action by individual organisations, initiatives facilitated by governments

- Winners and losers world
- Uncoordinated trade and shared resources
- Instability
- Selfishness
- Corruption prevents coordination

Sleeping Lions

Massive public mobilizations, international investments, informal trade, personal community, psychological resilience

- No win-win
- Latent capacity and wasted opportunities
- Revolutions that lead nowhere
- Leaders making money through crises

FRAGMENTED STATUS QUO

The set of scenarios developed by Vervoort *et al.* (2013) illustrate how participatory scenario development can be combined with modelling approaches to explore potential future drivers of change and their implications. The CGIAR Research Program on Climate Change, Agriculture and Food Security developed four socio-economic scenarios for Eastern Africa for the period 2010–2030 to inspire policy prioritisation, the development of research questions, and agenda setting aimed at improving food security, environmental management and enhancing rural livelihoods in the context of climate change.

Participating stakeholders included governments and their policy advisors, civil society, the research community and the media. They identified the direction and magnitude of change for a number of relevant indicators (semi-quantitative assessment) under the different scenarios, thus providing input for a quantitative approach using two agricultural economic models. Population growth and climate change were identified as the main relevant drivers applicable to all scenarios. Regional integration and governance were also considered as highly relevant, but were identified as key uncertainties that defined the different scenarios. A severe drought event was assumed in 2020–2022 across all scenarios.

Looking across the different scenarios, population growth and the influence of global markets are expected to hamper improvements in food availability, so that food access remains a challenge. The scenarios highlight that foreign investment needs to be well-managed to improve food security. The scenarios further highlight that food security and livelihoods are likely to take priority over environmental policies under all scenarios. A land use change tax could help minimize environmental degradation while regional food availability improves.

The highest demand for food is found under the *Policy Reform* archetype due to increased global demand for cereals and animal products, where cereals are increasingly used as livestock feed (MA, 2005). At the same time, increased yields reduce the need for the expansion of large crop areas in some locations, potentially freeing up land for bioenergy production (Smeets *et al.*, 2007; Erb *et al.*, 2012). Local and global demands are met by increasing agricultural intensification and aquaculture production, improving food security across the continent as most of the food is purchased rather than grown (WWF-AfDB, 2015). Similar to *Fortress World*, reliance on natural resources remains high under the *Local Sustainability* archetype, but regional or global support is available to avoid excessive pressures on the natural environment. Under the *Regional Sustainability* archetype, increased infrastructure and regional urbanisation are expected which promotes a change to richer consumption patterns (Lambin *et al.*, 2014), including increased consumption of marine resources (WWF-AfDB, 2015). Increased agricultural yields of particular cereals, may also lead to dramatically increased consumption of meat and dairy under this archetype.

5.4.4. Global trade and resource demand

Natural resource extraction contributes significantly to the GDP of many African countries and has the potential to catalyse further economic and social development (Cilliers *et al.*, 2011; WWF-AfDB, 2015). Uncultivated arable land in Africa is seen as a potential resource for increased agricultural production which could be used for either biofuel or meat production (Smeets *et al.*, 2007; Pfister *et al.*, 2011). Although there is substantial potential for growth, it is linked to great uncertainties around levels of foreign direct investment, governance and political stability. Increasing demand for agricultural products (cereals or biofuels), extractives (e.g., minerals or oil), and an increased demand for land, marine and freshwater resources (Crona *et al.*, 2010) also presents a challenge for sustainable development and exacerbates pressures on biodiversity and ecosystem services across the continent (UNEP, 2007; WWF-AfDB, 2015).

Under the *Market Forces* archetype, high global demand for resources is driven in particular by foreign direct investment and globalised trade. Resource-rich areas are likely to become short-term centres of economic development resulting in large-scale land conversion activities such as mining and agriculture (WWF-AfDB, 2015). The massive expanse of underused arable land in the Sahel (Lambin *et al.*, 2014) and many other regions of Africa (Erb *et al.*, 2012), is potentially subject to land grabbing for biofuel production. The proliferation of cash crops for a global markets increases tensions around land between small-scale farmers, pastoralists and big foreign corporations (Lambin *et al.*, 2014).

Under the *Policy Reform* archetype, increased global coordination and stronger central government lead to the improved distribution of wealth that could benefit both the environment and citizens (UNEP, 2016). However, despite agreeing to global sustainability criteria, the likelihood of negative impacts to biodiversity and ecosystem services remains high (MA, 2005; UNEP, 2016). Large, planned export corridors and supporting infrastructure is developed to exploit the significant mineral, oil or agricultural resources across Africa. The increased global trade could also increase the potential for spreading invasive species, despite improved regulatory agreements (MA, 2005).

Under the *Regional Sustainability* archetype, (UNEP, 2016) large-scale infrastructure corridors are also expected to be developed with locally sourced capital and resources, driving growth. However, both local and global trade foci are likely to occur (MA, 2005; Nakicenovic *et al.*, 2000). Both the *Fortress World* and *Local sustainability* archetypes suggest reduced global resource demand. Whereas the former is likely to be reduced due to an inward focus and low international trade, the latter is due to the increased rural focus of African countries which dissuades direct foreign investment. However, wealthier nations may still increase resource extraction in poorer nations (MA, 2005). These scenarios suggest that natural resource management is likely to be state-owned with countries looking after their own interests and providing little protection for common goods and biodiversity.

5.4.5. Climate change

Africa is one of the most vulnerable regions to climate change, raising concern around water stress and future prospects of food production (Narain *et al.*, 2011; IPCC, 2014). For example, in East Africa, crop yields are expected to decrease between 1-15% depending on the climate scenario (Thornton *et al.*, 2009). In addition, pest species benefit under several global warming scenarios, worsening the threat to livelihoods and agricultural yields (e.g., the coffee berry borer, *Hypothenemus hampei*) and further complicating decision-making (Jaramillo *et al.*, 2011). Sub-Saharan Africa is also considered to have the highest adaptation costs to climate change (Narain *et al.*, 2011), although these costs are significantly lower compared to the costs of anticipated impacts (van Vuuren *et al.*, 2014b). Some climate scenarios (e.g., RCP 2.6, Niang *et al.*, 2014) require a large uptake in carbon neutral transport fuels (e.g., biofuels) to reduce CO_2 emissions (Visconti *et al.*, 2011), some of which could be produced in Africa. While all scenarios considered adopt a global agenda for sustainable development which includes climate mitigation options, the impacts of climate change may impede much of the progress made towards improving socio-economic well-being across the continent (UNEP, 2016).

Across Africa, greenhouse gas emissions are expected to increase alongside increased industrialisation, deforestation and continued land-use and land cover change (UNEP, 2016). The highest global emissions scenarios can be found under the *Market Forces* archetype (i.e., RCP 8.5, Niang *et al.*, 2014; IPCC SRES A1, Nakicenovic *et al.*, 2000) and the *Fortress World* archetype (MA, 2005), culminating in expected temperature increases of between 2.6 and 4.8 degrees relative to 1986-2005 averages (IPCC, 2014). These scenarios indicate surface warming and the likelihood of reduced annual runoff for southern Africa (Collins *et al.*, 2013). The most optimistic climate pathway (i.e., RCP 2.6, Niang *et al.*, 2014) can be found under the *Policy Reform* archetype despite the continued use of fossil fuel based energy sources (e.g., oil, gas and coal). Here, climate mitigation measures are reactionary and happen too late as society responds by adapting to impacts of climate change (e.g., decreasing air quality) rather than reducing emissions early (MA, 2005).

Under the *Regional Sustainability* cluster of scenarios, a global agenda for sustainable development which includes a strong focus on climate mitigation is adopted. Yet, despite the adoption of a low emission scenario, reduced material usage and increased use of clean efficient technologies, temperatures are expected to increase between 1.1ºC and 2.6ºC (RCP 4.5, Niang *et al.*, 2014). Under the *Local Sustainability* archetype decentralised low carbon energy infrastructure is developed (e.g., micro-hydro, solar and wind). However, the timing of this adoption occurs in the latter half of the century as technology transfer is not as rapid as under the *Regional Sustainability* archetype. This results in emissions peaking before they eventually decline, with an increase in temperatures ranging between 1.4ºC and 3.1ºC (RCP 6, Niang *et al.*, 2014), enough to compound stresses on water resources and local agrarian initiatives (IPCC, 2014).

5.4.6. Uncertainties, gaps and key research needs

While most of the scenario studies agree on the direction of potential scenario drivers under particular archetypes (Table 5.3), not all studies indicate the same magnitude of change. This is due to differences in assumptions, as well as differences in the linkages between scenario storylines and models. Some studies have strong linkages between the scenario storylines and models (e.g., Nakicenovic, 2000; MA, 2005 and IPCC assessments) while other studies are largely qualitative (e.g., WWF-AfDB, 2015). While more quantitative assessments can help check and refine narrative storylines, they may also constrain the potential outcomes to those based on current understanding of the relationships between key variables, such as consumption patterns and environmental impacts.

Most of the assessments focus on a similar set of key drivers. In a comparison with Chapter 4, there are many drivers that have not been considered in scenarios of future development pathways across Africa. For example, there are a limited number of scenarios and models which consider drivers related to invasive species introductions, rapid migration due to conflicts and natural hazards, and land tenure issues linked to land and water grabbing, or scenarios that address the impacts of urbanisation on energy demand, rates of charcoal consumption, sanitation needs, or pollution in Africa. The intensity and frequency of many of these underexplored drivers are likely to increase in the future and warrant further research and better incorporation into scenario studies. In addition, there are few scenarios that look at the compounding impacts of multiple drivers on the ability of social-ecological systems to provide ecosystem services (Adano *et al.*, 2011).

5.5. Biodiversity and nature’s contributions to people

Of the major studies considered in Table 5.2, only the Millennium Ecosystem Assessment (MA, 2005) has provided primary analyses of the changes in biodiversity and ecosystem services as a function of possible future scenarios. The other core reports provide general observations about the likely consequences of the storylines for ecosystems (as detailed in Box 5.2), rather than specific analyses. This section therefore focuses on findings from the MA scenarios, interpreting them specifically for the African region, and complements this with primary analysis from the systematic literature review, and where possible, with additional information from the other core reports (Nakicenovic *et al.*, 2000; UNEP, 2007; Niang *et al.*, 2014; WWF-AfDB, 2015). Findings are synthesized in terms of key ‘themes’ identified in the systematic review, and summarised in Table 5.4.

5.5.1. Biodiversity: Habitat Loss

Within the African context, the *Fortress World* archetype suggests far more severe habitat fragmentation with subsequent ecosystem loss and land degradation than the *Market Forces*, *Policy Reform*, *Regional Sustainability* or *Local Sustainability* archetypes. The MA predicts global habitat losses of 20% by 2050 under its *Fortress World* equivalent, (‘Order from Strength’), with warm mixed forests and savannas—typically found in Africa—suffering the largest losses (MA, 2005). In contrast, both the *Policy Reform* and *Local Sustainability* archetypes (‘Global Orchestration’ and ‘Adapting Mosaic’ under the MA scenarios), yield intermediate habitat losses. The *Regional Sustainability* has the lowest percentage habitat loss (13%) (MA, 2005), declining deforestation rates by 2050 (Alcamo *et al.*, 2005), and biodiversity change is comparably lower than under other scenario archetypes (Biggs *et al.*, 2008).

Table 5.4: Summary of the relative trajectories of biodiversity and nature's contributions to people (NCP) effects across different archetypes. Arrows indicate an increase (↗), decrease (↘), or no change (→) in biodiversity and ecosystem function under each scenario type. Within a cell, arrows represent the main scenario reports in the following order: IPCC; MA; GEO4; WWF/GEO6. If a report does not cover an archetype, this is symbolised by '0', whilst if a report does not explicitly address a specific element, this is indicated by an 'X', or a '?' to indicate knowledge gaps and uncertainties around assessment for Africa. The colour of the cell indicates the overall trend across the reports, where green indicates an overall increase, orange indicates overall decrease, purple indicates contradictory trends, and no colour indicates no overall change or unknown effects.

BIODIVERSITY AND NATURE'S CONTRIBUTIONS TO PEOPLE	FORTRESS WORLD				MARKET FORCES				POLICY REFORM				LOCAL SUSTAINABILITY				REGIONAL SUSTAINABILITY			
BIODIVERSITY[a]	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF
Terrestrial	↘	↘	↘	O	↘	O	↘	↘	O	↘	↘	↘	↘	↘	O	→	↘	↘	↘	↘
Freshwater	↘	↘	X	O	↘	O	X	↘	O	↘	X	↘	↘	↘	O	→	↘	↘	X	↘
Marine	↘	↗[1]	↘	O	↘	O	↘	↘	O	↗[1]	↘	↗	↘	↗[1]	O	→	↘	↗[1]	↘	↘
Range shifts[b]	↗	↗	X	O	↗	O	X	X	O	↗	X	X	↗	↗	O	X	↗	↗	↗	X
NCP																				
Terrestrial food & feed production[c]	→[4]	↘	↗	O	→[4]	O	↗	↗	O	↗	↗	↗	→[4]	↘	O	→	→[4]	↗	↗	→[2]
Marine food & feed production[d]	↘	↘[1]	→[3]	O	↘	O	↘	↘	O	↗[1]	→[3]	↗	↘	↗[1]	O	↘	↘	↘[1]	→[3]	↘
Regulation of freshwater quantity, flow and timing	↘	↘	↘	O	↘	O	↘	↘	O	↘	↘	↘	X	↘	O	→	X	↘	↘	↘
Energy[e]	?	↗	↗	O	?	O	↗	X	O	X	↗	↗	↗	↗	O	→	↗	↗	↗	X
Habitat creation and maintenance[f]	X	↘	↘	O	X	O	↘	↘	O	↘	↘	↘	X	↘	O	→	X	↘	↘	↘
Pollination	X	↘	X	O	X	O	X	X	O	↘	X	X	X	→	O	X	X	↗	X	X
Regulation of hazards and extreme events	X	↘	X	O	X	O	X	X	O	↘	X	X	X	↗	O	X	X	→	X	X
Regulation of climate	X	↘	X	O	X	O	X	X	O	?	X	X	X	→	O	X	X	→	X	X

↗ Increase ↘ Decrease → No change O Not covered ? Knowledge gap or uncertainities

Overall increase (green) Overall decrease (orange) Contradictory trends (purple) No overall change or unknown effects (no colour)

a. changes to biodiversity / species as a result of ecosystem transformation
b. consequences of increased range shifts may be positive or negative, species dependent, and table reflects the extent of shifts occurring across systems rather than the outcome
c. as reflected by modernisation of agricultural sector and consequences on rainfed agriculture
d. as reflected by biomass of capture fisheries and open-ocean productivity
e. production of biomass-based fuels, specifically biofuel crops
f. consequences as a result of habitat loss and species changes
1. as measured through biomass diversity in Benguela system and catch landings
2,3,4. in GEO6/WWF, there are both marked localised improvements due to more regionally integrated & focused conservation efforts ('sustainability brightspots', see Box 5.2), but also increased degradation beyond these areas, with the horizontal arrow representing the cumulative outcome; similarly for GEO43, where the horizontal arrow reflects different responses to the total biomass landings of different trophic groups as a result of fishing strategies, and for IPCC4 where the horizontal arrow reflects strong regional and crop differences in model predictions for Africa

Africa's warm mixed forests, savanna biomes across the continent, and the broadleaf tree cover of tropical Africa, are most at risk of transformation (MA, 2005; Hua *et al.*, 2014; Betts *et al.*, 2015). Modelling studies indicate that under *Policy Reform*, habitat losses of ~27% may occur across tropical Africa alone, with the Congo forests contracting and fragmenting (most pronounced in Cameroon, Central African Republic, Guinea, Gabon and Uganda) and predictions of up to 76.6% and 96.7% losses in the Guinean forest block and African dry forests respectively (Aleman *et al.*, 2016). In southern Africa, specifically Angola and Zambia, land transformation is more pronounced under *Policy Reform* than under *Local Sustainability* (Biggs *et al.*, 2008), despite the two archetypes having similar 'intermediate' levels of habitat loss globally (MA, 2005). Furthermore, southern Africa shows potential losses of up to 65% of sensitive Fynbos and Succulent Karoo biomes under exacerbated climate change projections using bioclimatic approach (Rutherford *et al.*, 2000). Structural ecosystem change involving both increases and decreases in woody plant cover in South Africa savannas are also expected (Midgley *et al.*, 2011).

There is some evidence that, regardless of the archetype, habitat loss through land-use change may have more severe consequence in the short-term than a changing climate. Analysis of climate and land-use change scenarios by Jetz *et al.* (2007) indicate that projected land-use change will contribute the most to the future decline in bird populations globally, with West Africa being among the areas of greatest concern. This is particularly apparent for the coral reefs along the coast of Madagascar, where changes in sediment supply to the reefs associated with climate effects is outweighed by the effect of deforestation, regardless of the scenario (Maina *et al.*, 2013). A similar effect is evident for forests and savannas across sub-Saharan Africa, where land-use change effects are more significant than changing precipitation by 2070 under both *Regional Sustainability* and *Policy Reform* (Aleman *et al.*, 2016). These findings highlight the need for sustainable land-use choices along with effective climate mitigation and adaptation measures to ensure the long-term persistence of biodiversity. Maina *et al.* (2015) demonstrate how scenarios can be used in conjunction with habitat mapping and climate models to determine appropriate future marine resource conservation strategies (see Box 5.4).

In terms of aquatic ecosystems, total anthropogenic water use may increase by as much as 170% across Africa under *Fortress World* scenarios, pointing to higher levels of water re-use under this archetype (Weiß *et al.*, 2009) and deteriorating water quality (van Vliet *et al.*, 2013), with severe consequences for the functionality of aquatic ecosystems, particularly wetland systems (Todd *et al.*, 2009; Milzow *et al.*, 2009; Weiß *et al.*, 2009; van Vliet *et al.*, 2013). The Senegal River, Limpopo River, White Nile River, and Shebelle River basins all become categorised as 'severe water stress[-ed]' under this archetype, and the wetlands north of Lake Victoria become severely compromised, and are likely to become endangered by 2050 (Weiß *et al.*, 2009). The functionality of the Okavango Delta is at severe risk under *Fortress World*, with impacts most pronounced for minimum monthly flows. Reductions in minimum flow of 27% (2050–79) and 36% (2070–99) are predicted (compared to predictions of 20% (2050–79) and 29% (2070–99) under *Local Sustainability*), effectively decreasing its functional size as woody plant species colonise the emergent dry areas (Todd *et al.*, 2009). However, the contraction of the wetland is not homogenous across the Delta (regardless of the scenario), and under *Fortress World*, the central wetlands and Lake Ngami (south) are most severely affected, while changes to minimum flooding thresholds result in the Selinda Spillway (north-east) no longer being functional by 2099 (Milzow *et al.*, 2009).

5.5.2. Biodiversity: Species range shifts

Under all scenario archetypes, there are increasing numbers of climate-affected ecosystems over time; only in the *Regional Sustainability* does the number of habitats affected decrease after 2050 (in the absence of adaptation) due to greenhouse gases stabilising, and slowing temperature change (MA, 2005; WWF-AfDB, 2015; Belle *et al.*, 2016). The effects on species ranges and richness are more pronounced under higher emission scenarios globally (IPCC, 2014), i.e., *Regional Sustainability* (~ RCP 4.5, Niang *et al.*, 2014) < *Local Sustainability* (~RCP 6.0, Niang *et al.*, 2014) < *Market Forces* and *Fortress World* (~RCP 8.5, Niang *et al.*, 2014). Similar patterns hold at the African level, with the *Local Sustainability* and *Regional Sustainability* archetypes demonstrating the same general trends of range contraction as *Fortress World* and *Market Forces,* but with less intensity (Kuhlman *et al.*, 2012; Garcia *et al.*, 2014;

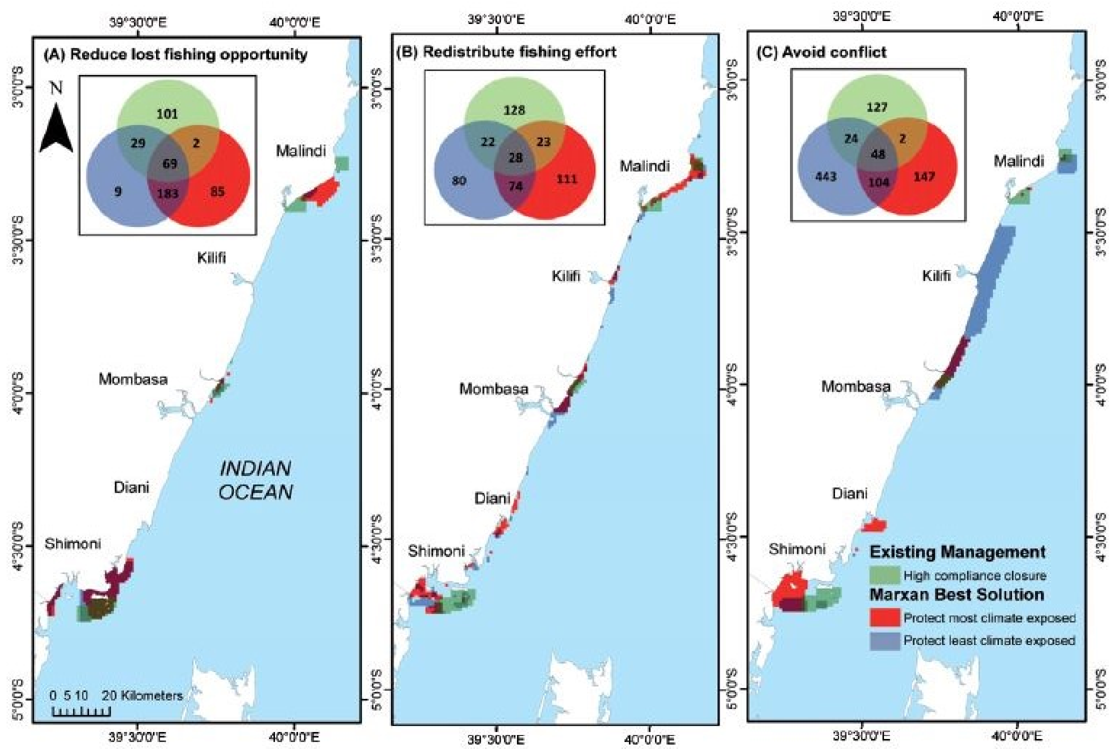
Mokhatla *et al.*, 2015; Walther *et al.*, 2014; Simaika *et al.*, 2015). Across all archetypes, range contractions are more pronounced for localised endemics (i.e., Houniet *et al.*, 2009; Busch *et al.*, 2012; Kuhlman *et al.*, 2012; Mokhatla *et al.*, 2015; Simaika *et al.*, 2015). Similar patterns are expected across all taxa, although uncertainty increases after mid-century (Baker *et al.*, 2015; Box 5.5), and the exact response to future climate change is species specific (Coetzee *et al.*, 2009; Houniet *et al.*, 2009; Hole *et al.*, 2009; Kuhlman *et al.*, 2012; El-Gabbas *et al.*, 2016; Taylor *et al.*, 2016).

Box 5 4 Designing climate resilient marine protected areas for the East African coast. Source: Maina *et al.* (2015).

Within the Western Indian Ocean region, resource degradation and climate change effects have driven the need for improved management of the region's coral reefs. This is essential to ensure long-term human well-being linked to food security, marine conservation and sustaining opportunities for developing the economy of the region from both a tourism and resource use perspective.

Maina *et al.* (2015) developed habitat maps based on detailed satellite imagery combined with ground truthing to assess the effectiveness of current management practices in protecting habitat diversity. Thereafter three spatial prioritisation scenarios for the future were developed which presented differing objectives. These were 1) minimising lost fishing opportunities, 2) redistributing fishing effort away from overfished areas, 3) minimizing resource use conflicts. Priority area selection was undertaken using the conservation planning tool Marxan in conjunction with these scenarios. Area prioritisation was then further constrained by either protecting the areas least or most exposed to climate stress.

The outcome of this analysis highlighted that whilst current approaches appear to maintain specific marine habitats, there is a clear need for rezoning and establishing marine protected areas that more accurately represent habitat diversity and are anticipatory of climate change into the future.



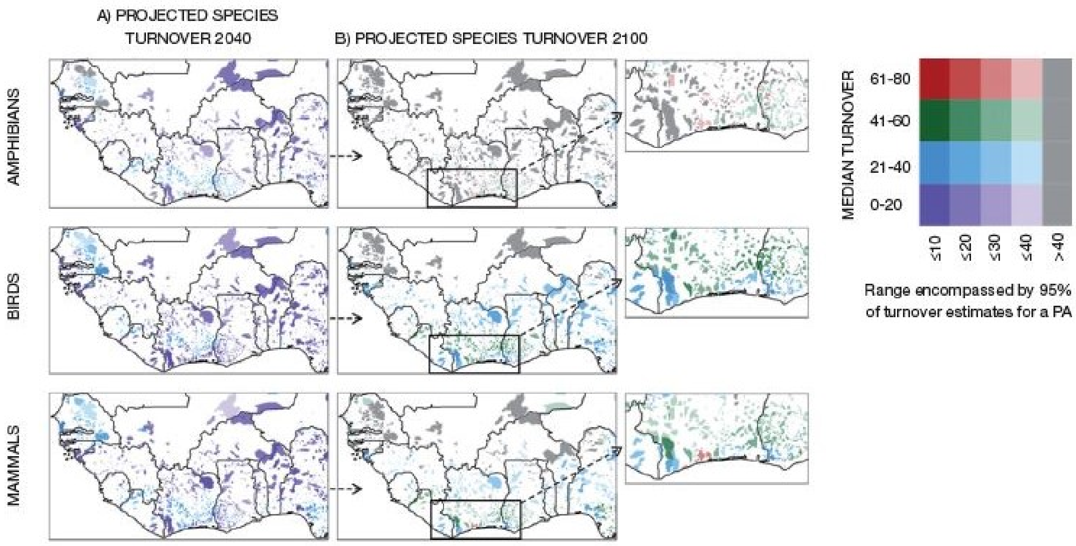
Maina *et al.* (2015) developed three spatial prioritisation options for future conservation areas along the Kenyan coast. Conservation areas were selected in the most cost-efficient scenario of 100 Marxan runs, based on prioritization analysis when (A) reducing the cost of lost fishing opportunity (B) redistributing fishing effort to minimize impacts and (C) avoiding potential conflicts between ocean-based activities and conservation. Blue represents priority areas when aiming to protect areas least exposed to climate change, while red represents priorities when aiming to protect areas most exposed to climate change. Existing high compliance closures are shown in green. Inset venn plots show the area selected under each objective, with overlapping sections representing existing high compliance closures which were identified as priorities when attempting to protect either the most or least exposed areas to climate change.

Box 5 5 Species range shifts in West Africa under climate change. Source: Baker *et al.* (2015).

Protected areas underlie conservation efforts globally, and are the primary mechanism through which biodiversity is protected from anthropogenic impacts. However, climate change increasingly challenges the effectiveness of the existing protected area networks. Static protected areas are typically unable to respond as species ranges potentially shift beyond their current boundaries with changing temperatures and precipitation.

West African biodiversity is likely to suffer severe consequences from a changing climate. Assessing the future climate suitability of the current protected area network is a high priority given the high levels of endemism and the high irreplaceability value of the existing protected areas. Thus, an assessment of future climate change impacts for vertebrate fauna across the West African protected areas using the HADCM Global Circulation Model (GCM) under Local Sustainability (SRES A1B emission scenario) was undertaken. The assessment included species' specific dispersal capabilities under future range shifts, while accounting for the spatial and temporal patterns of climate change impacts, and uncertainty in these impacts, across the existing protected area network.

For all taxonomic groups (birds, amphibians, mammals) assessed, species turnover across the region is predicted to increase by 2100. There is high uncertainty for birds and amphibians, but consistent patterns of impacts for all taxa projected by early to mid-century (Baker *et al.*, 2015).



The figure shows the spatial pattern of species turnover across the region's protected area network for two focal future time periods (A) 2040 and (B) 2100. The focal plot shows the Guinea forest region, where many of the highest impacts are projected to occur for all three taxonomic groups. Colours reflect the cater projections; the intensity indicates the range of allegory encompassing the median projected turnover. Colour intensity reflects uncertainty in turnover values encompassed by 95% of the projected estimates of turnover for each protected area.

Local Sustainability suggests the 'least-bad' scenario for African terrestrial biodiversity generally (Visconti *et al.*, 2011), while *Fortress World* the worst (terrestrial mammals: Visconti *et al.*, 2011; dry argan woodlands: Alba-Sánchez *et al.*, 2015; South African dragonfly species: Simaika *et al.*, 2015). Higher temperatures under *Fortress World/Market Forces* archetypes predict higher risks of severe change to African savanna ecosystems (Warszawski *et al.*, 2013). Thickening of woody cover in South African savannas under *Fortress World* (Nakicenovic *et al.*, 2000; A2 scenario) (Midgley *et al.*, 2011), is expected to lead to a loss in bird species richness and degradation of habitat for cheetah (Muntifering *et al.*, 2006; Sirami, 2009). The expansion of moist Afromontane forest and Combretum–Terminalia woodlands in East Africa (Ethiopia) is possible under *Market Forces*, *Fortress World* and *Policy Reform*, with a larger extent of expansion under higher emission scenarios (van Breugel *et al.*, 2016). In Central Africa, both *Market Forces* (A1Fl) and *Local Sustainability* (B2) predict increased precipitation in the Lake Chad region, but only under *Local Sustainability* (B2) is it likely sufficient to support vegetation growth, displacing the desert limit northwards (Delire *et al.*, 2008), perhaps with consequences for the Great Green Wall Initiative in the Sahel.

Under higher emission scenarios, xerotypic species may benefit initially from reduced water availability compared to montane species already at their climatic range limits, regardless of the specific scenario (i.e., Marshall *et al.*, 2010), as many species that favour hotter temperatures, e.g., Egyptian reptile taxa (El-Gabbas *et al.*, 2016). The literature shows reasonable consensus that current conservation areas across Africa are generally not well aligned with future range shifts of focal species, regardless of the scenario (e.g., *Acacia* spp., East Africa: Marshall *et al.*, 2012; herpetofauna, Morocco: Martínez-Freiría *et al.*, 2013; South African dwarf succulents (*Conophytum* spp.): Young *et al.*, 2016). This suggests the need for more expansive and more strategically targeted protected areas in the future. In South Africa, there is some indication that even under moderate to high climate change, i.e., SRES A2 (*Fortress World*), A1FI (*Market Forces*) and A1b (*Local Sustainability*) (Nakicenovic *et al.*, 2000), conservation needs can be accommodated in the existing protected area network with comparatively minor expansion (Hannah *et al.*, 2007; Young *et al.*, 2016). The costs associated with ensuring effective conservation under higher emission scenarios are expected to be greater, as has been demonstrated in Madagascar (Busch *et al.*, 2012). Across Madagascar, the per species cost of securing 74 forest endemics under *Fortress World* are estimated at to $1,242,000–5,192,300 (2000–2080) compared to $935,900–4,094,600 for the same period in the lower-emissions *Local Sustainability* archetype (Busch *et al.*, 2012).

Aquatic ecosystems show similar trends to terrestrial, with more severe consequences expected under *Market Forces* and *Fortress World* archetypes compared to *Policy Reform*. Under *Fortress World,* reductions of water and sediment inflow into wetlands cause widespread declines in migratory bird populations as aquatic ecosystems rapidly degrade (Bohensky *et al.*, 2006). Studies indicate that significant unquantified endemic biodiversity in the Okavango Delta and other wetlands will be put at risk as feeder rivers lose as much as 30% of their flow by 2050 (De Wit *et al.*, 2006). For coastal systems, *Market Forces* and *Fortress World* predict sea surface accretion rates will only keep pace with expected sea level rise to 2070 (basin mangrove systems), and 2055 (fringe mangroves), with submergence and degradation likely beyond those periods. In contrast, under the lower levels of sea level rise projected under *Policy Reform*, both fringe and basin mangrove systems are expected to remain above the expected sea level rise until 2100 (Sasmito *et al.*, 2015). Regionally, East African islands' fringe mangroves are potentially most at risk (Sasmito *et al.*, 2015). In South Africa, the latitudinal range limit of mangrove forests tracks consistently further south under *Fortress World* than *Local Sustainability*, with *Local Sustainability* predictions suggesting smaller initial extension southwards by 2020, reverting northwards thereafter 2050 (Quisthoudt *et al.*, 2013). Within the oceans around Africa, new climate source areas (i.e., locally novel climatic conditions, now isolated from areas of previously similar climate) appear at the equator, and are double in size for *Fortress World* compared to the low warming scenario of *Regional Sustainability* (Burrows *et al.*, 2014). The appearance and size of the climate sources will have important consequences for ocean migrants tracking isotherms—these locally novel climate conditions lack connection routes to similar climatic areas, and likely become inaccessible. Species richness here may thus decline under multiple scenarios, but more significantly in *Fortress World,* as leaving migrants are not replaced by new arrivals (Burrows *et al.*, 2014).

5.5.3. Provisioning services

The literature highlights increased needs for provisioning services across Africa in the future, particularly those linked to **food production**. However, there are mixed results across scenarios and between core reports (most notable under *Fortress World*, *Regional Sustainability* and *Local*

Sustainability archetypes) about whether the productivity of the agricultural system will meet this need. There is strong regional variability in crop performance across Africa, with the negative consequences of changing temperatures and rainfall most pronounced in areas south of the Sahel (Niang *et al.*, 2014), and most notable under *Fortress World*. In contrast, under *Market Forces*, high elevation areas in East Africa may experience productivity gains owing to increasing temperatures under an A1FI scenario (Niang *et al.*, 2014). Under *Policy Reform* and *Market Forces*, although yield productivity may increase initially due to a focus on agricultural intensification (MA, 2005; UNEP, 2007), concerns remain about the unintended longer-term consequences of increasing productivity in the short-term. Under *Regional Sustainability*, agricultural modernisation, incentives for low-impact agriculture and a focus on technical innovation will improve crop productivity (Nakicenovic *et al.*, 2000; MA, 2005; UNEP, 2016), and this results in less agricultural expansion and lower levels of habitat loss. However, the over-reliance on a narrow range of crop services (MA, 2005), and a dependency on cash crops (WWF-AfDB, 2015) to optimise production efficiency, have substantial negative consequences for the longer-term resilience of the agricultural production system. Under *Fortress World*, increased consumption, accompanied by slow improvements in agricultural productivity drives agricultural expansion (Nakicenovic *et al.*, 2000; MA, 2005; UNEP, 2007) with negative consequences for habitat integrity. Under this archetype, Visconti *et al.* (2011) suggest this expansion may be as much as ~71% to meet pasture requirements and ~56% for cropland by 2050, while Alcamo *et al.* (2005) model a possible increased demand for agricultural land in sub-Saharan Africa alone of 11 to 17 million hectares between 2000 and 2050. In the West Sahel, this expansion of agriculture may result in increased local conflict between pastoralists and farmers over spatial resource requirements, undermining the already fragile relationship between land-users (Lambin *et al.*, 2013).

The contribution of **biofuel** to energy use is set to increase across archetypes after 2025/2030 (MA, 2005; UNEP, 2007), most notably under *Regional Sustainability* and *Policy First*. Under *Local Sustainability*, global biofuel contributions to the agricultural system increases, but in Africa, agricultural modernisation is spatially heterogeneous, resulting in inconsistent responses to ensuring local renewable energy options on the continent (UNEP, 2016). In general, significant uncertainty and knowledge gaps remain around biofuel production in Africa (Niang *et al.*, 2014), particularly with respect to socio-ecological sustainability considerations and land-use trade-offs (i.e., *food versus fuel*), and how trade-offs are manifest both spatially and within communities (Niang *et al.*, 2014), with implications for livelihood security.

Under *Fortress World* in general, the livelihoods of the rural poor are particularly compromised as natural systems deteriorate (Bohensky *et al.*, 2006), are made inaccessible through commercial activities, and unsustainable rural land-use choices contribute to ecosystem degradation (Lambin *et al.*, 2013). High levels of social inequity that exist between rich and poor, men and women, rural and urban, and different regions (UNEP, 2006; Niang *et al.*, 2014) is a clear indication of government failures in ensuring equitable livelihoods, forcing communities to [over-]exploit limited water, food and fuel reserves that they can access (Bohensky *et al.*, 2006; UNEP, 2006). As a result, many rural communities may resort to poaching and illegal harvesting to ensure food and energy security (Bohensky *et al.*, 2006; WWF-AfDB, 2015), which is concerning given current existing trends in this regard (Chapter 4).

The demand for **marine food and feed** increases under all scenarios (MA, 2005; Niang *et al.*, 2014), yet in general, the productivity of marine fisheries tends to decline owing to increased fishing pressure and the negative impacts of climate change. Marine fisheries in Africa rely heavily on protective reef systems and coastal upwelling, yet ocean acidification and increasing sea surface temperatures will have likely severe negative consequences for fish stocks in these systems (Niang *et al.*, 2014). Under *Local*

Sustainability (~A1B) in particular, West Africa is at considerable risk of the negative impacts of climate change, with the declines in marine resources that may result in significant consequences for the coastal economy here (Niang *et al.*, 2014). Where fisheries response indicates mixed results, this is due to a diversity in fishing strategies affecting the fish targeted (UNEP, 2007), i.e., harvesting of demersal versus pelagics, with models predicting clear trade-offs in the diversity of fish landed and production within the fisheries system (MA, 2005). While the increased investment in aquaculture across scenarios may potentially meet the increased demand for fish as capture fisheries deteriorate (MA, 2005), there remain concerns around the long-term sustainability of this industry (MA, 2005; UNEP, 2007; UNEP, 2016), and whether it will expand to a sufficient scale in Africa to meet the region's increasing fish demands by 2020 (Niang *et al.*, 2014). Under *Policy Reform*, the focus on the green economy instead of the blue (UNEP, 2007; UNEP, 2016), and the technological innovations of *Regional Sustainability* facilitating rapid aquaculture expansion (MA, 2005), may eventually reduce the harvesting pressures on capture fisheries (MA, 2005; UNEP, 2016). Yet to support this growing industry, small pelagic fish are increasingly targeted for aquaculture feed purposes—raising the value of catches even as their weights decline (MA, 2005)—potentially undermining the functioning of both natural marine and freshwater systems further. Additionally, the longer-term biodiversity consequences of aquaculture escapees and eutrophication from the industry's waste may be substantial even as food production benefits (UNEP, 2016).

In terms of **water availability**, analyses of the MA scenarios using two models of water availability (WaterGAP and AIM; MA, 2005) indicate that globally the differences between scenarios are modest until 2050 (with *Policy Reform* > *Fortress World* = *Local Sustainability* > *New Sustainability*), but these intensify with time. In sub-Saharan Africa, water availability drops by ≥ 50% under all scenarios by 2100, and is associated with an increase in water stress as large increases in return flows of wastewater discharge into watersheds and degrades water quality (MA, 2005). These changes may become most critical under *Fortress World*, despite this scenario being associated with lower levels of water availability and extraction than *Policy Reform*. Under *Fortress World*, sub-Saharan Africa has return flows increasing by 100% by 2050, affecting the largest relative total population (MA, 2005). Northern and southern Africa are also expected to become severely water-stressed under *Policy Reform*, although to a lesser extent than under alternative archetypes (Alcamo *et al.*, 2005), and total anthropogenic water use may increase by 36% across Africa (Weiß *et al.*, 2009). *Policy Reform* predicts that between 15–40% of Africa will experience increases in time spent under drought conditions (compared to *Local Sustainability*: 20–50%), but the possibility of more aggressive climate mitigation policies that manifest through technological advances under this archetype, suggest that the future patterns of drought may yet be reduced (Taylor *et al.*, 2013).

Environmental flows within the productive Nile River system, while still categorised as under 'severe water stress', improve under *Policy Reform* compared to scenario alternatives (Weiß *et al.*, 2009). However, under this scenario in South Africa, river flow becomes increasingly impounded and diverted for industrial use as global markets transform the landscape, fuelling conflict over extraction needs between agriculture and industries that drive economic growth (Bohensky *et al.*, 2006). Under *Local Sustainability*, the expansion of agriculture into marginal lands further degrades soil and water quality (Bohensky *et al.*, 2006), decreasing watershed services by 2025 (Notter *et al.*, 2013). Under *Local Sustainability*, the literature indicates that the risk of decreased freshwater runoff is particularly pronounced for South and West Africa (Scholze *et al.*, 2006; Taylor *et al.*, 2013), and local water and energy interventions, i.e., rainwater harvesting and the use of community woodlots, becomes more prevalent in rural areas (Bohensky *et al.*, 2006; Lambin *et al.*, 2014).

De Wit *et al.* (2006) suggest that even under a relatively optimistic *Regional Sustainability* scenario (B1), a decrease in perennial rainfall would affect surface water access across 25% of Africa by 2100. Given that river channels and basin watersheds demarcate nearly 40% of the international political borders across the continent, declines in perennial flow, and thus water security, will likely have significant water governance implications. The authors suggest that precipitation in Southern, Northern and Western Africa will likely suffer the most notable declines under this scenario. Cape Town could lose almost half of its perennial water supply by the end of the century, and any precipitation changes in the narrow east-west band that separates the Sahara from Central Africa would have substantial repercussions for important water bodies, including the Nile Basin's Sudd swamps, Niger River and Lake Chad (De Wit *et al.*, 2006). There may be insufficient rainfall to allow for perennial river networks in the Sahara in the medium- to long-term (De Wit *et al.*, 2006), although the response of the Sahara desert's range limit is more complex, shifting latitudinally SW-NE (De Wit *et al.*, 2006; Delire *et al.*, 2008). Such changes to surface water may have implications for the Great Green Wall Initiative in the Sahel (OSS, 2008). Given the political commitment to the initiative, as well as current concerns about existing water systems (O'Connor *et al.*, 2014), this will need to be assessed under a range of likely climate futures. Such assessments are notably absent at present.

5.5.4. Regulating Services

The MA details the global deterioration of **pollination** services across all scenarios, as habitat losses, species range shifts and declines in species richness affect pollination effectiveness. Only under *Local Sustainability* is there a possibility of localised improvements owing to regional ecosystem management programmes, and thus the maintenance of pollination capacity at local sites. Under *Regional Sustainability*, engineered pollination solutions may become successful in the longer-term and play a profound role in the face of ongoing declines in pollination capacity globally, through for instance the development of self-pollinated crop strains (MA, 2005). For Africa specifically, the existence of large data gaps around wild pollinators and their services (species identity, distribution and abundance) precludes any conclusive statements about pollinator impacts for the continent (IPBES, 2016). However local declines are already evident (IPBES, 2016), which when combined with *i)* well-established evidence that indicates that the rate of climate change under mid- to high emission scenarios will exceed the maximum speed at which many important pollinator groups (e.g., bumble bee and butterfly species) can disperse or migrate (IPBES, 2016), and *ii)* the well-established lag effect and delayed response times in ecological systems, suggests that the full impacts of climate change on pollinators and pollination services will only become apparent in several decades (IPBES, 2016), and suggests likely further deterioration of pollinator services in Africa under all scenarios.

Technological innovation under *Regional Sustainability* points to successful deliberate engineered solutions to improve the **regulation of climate and storm protection** (MA, 2005). However, improvements in climate regulation services are largely to the benefit of wealthier countries. For the poorest countries, some of which will likely be located on the African continent, widespread deterioration of ecosystems causes general declines in climate and storm regulation. A decline in regulating services in poorer countries is particularly significant under *Fortress World*, with Africa highly vulnerable due to extensive losses of forest and savanna systems as agriculture is prioritised (MA, 2005). In contrast, under *Local Sustainability*, the prioritisation of more integrated ecosystem management approaches and the ecological benefits that result (UNEP, 2016), lead to regional improvements in storm protection (MA, 2005). Similarly, localised conservation improvements in 'sustainability hotspots' supports lower rates of habitat loss in these areas (MA, 2005) and thus potential declines in regulating services.

Higher emission scenarios typically have larger carbon uptake rates due to faster temperature increases and higher atmospheric CO_2 levels (Alcamo *et al.*, 2005; MA, 2005), with the largest uptakes occurring in regions where extensive forests dominate (MA, 2005). *Policy Reform* prioritises old-growth forests for this reason, but there is considerable uncertainty as to the global success of such policy responses (MA, 2005). The systematic review further indicates inconsistent climate regulation benefit across the African continent under different scenarios - due to the trade-offs between temperature and water availability under different scenarios. In Central Africa, under both *Market Forces* and *Fortress World* archetypes (~RCP 8.5, Niang *et al.*, 2014), Net Primary Production (NPP, a proxy for carbon sequestration by plants) may increase in the woodlands of Sudan (Alam *et al.*, 2013). In contrast, in Southern Africa, decreased water availability may reduce NPP, regardless of any increases in tree coverage (Yu *et al.*, 2014). While the savannas across Southern Africa may currently be bigger stores of organic carbon than initially thought (Dintewe *et al.*, 2014), field measurements indicate that their storage effectiveness will likely decline in the future, as the region warms and dries into 2100 (Dintewe *et al.*, 2014). Given the limited evidence exploring the role that African ecosystems play in climate regulation, and how this varies under different scenarios and temperature and precipitation regimes, this points to a research gap.

5.5.5. Uncertainties, gaps and research needs

The scenario studies identified in the systematic review that focus on particular places or sets of species align broadly with the trends observed by the core scenario reports assessed in this chapter, with higher emissions futures having more severe consequences for biodiversity and ecosystem services. However, there is relatively little published literature that considers the full suite of scenario archetypes for Africa, and few comparable studies on the same species groups, precluding the assessment of collective responses per taxon at this time. For the most part, this results in low resolution and levels of certainty about the future of biodiversity and NCP in Africa. Specifically, there is a need for further scenarios and modelling work on tropical ecosystems that takes into account the different levels of biotic interactions and that incorporates sufficient geographical (scale issues), ecological and taxonomic resolution (Kissling *et al.*, 2010; Jaramillo *et al.*, 2011).

The climate scenarios considered by the studies identified in the systematic review, and described in this section, are mainly driven by the IPCC emissions scenarios (Nakicenovic *et al.*, 2000; Niang *et al.*, 2014; and IS92), and to a lesser extent, the Millennium Ecosystem Assessment, and the Global Environment Outlook 4. Most literature focuses on emission scenarios that fall within the *Fortress World* and *Local Sustainability* archetypes, either individually as a single representation of a possible future, or by making comparisons, i.e., comparing a high versus medium emissions future. This suggests a need for considering a wider set of emissions futures in future analyses. The choice of emissions frameworks in the literature to date reflects the time-lags between the publication date of the scenario framework and wider use by the scientific community (van Vuuren *et al.*, 2014a). Greater use of Africa specific scenarios such as the recent WWF/GEO6 (WWF-AfDB, 2015; UNEP, 2016) scenarios would help broaden the range of futures analysed.

There is a strong spatial bias towards biodiversity studies in Southern Africa (South Africa specifically), and to a lesser extent, East Africa. Central Africa is most poorly represented. The direct links between biodiversity features, ecosystem services and human livelihoods are not well explored. Instead, most of the literature focuses on forecasting species' range shifts, extinction risk and habitat loss. This points to an urgent need for making the biodiversity and ecosystem services benefit linkage more explicit in future scenarios work.

5.6. Human well-being, poverty and inequality

As highlighted in Chapter 2, many aspects of human well-being have improved for much of Africa's population over the last 50 years: poverty has declined, better health care is available, and trade and education are opening up opportunities for the continent's citizens (AfDB, 2014). But it is also clear that progress has been patchy, and major challenges remain, both within and between countries. The impact of environmental change on people's well-being in the current African context is discussed in detail in Chapter 2. Building upon this foundation, the following section considers human well-being under a range of future scenarios for Africa in 2030 and beyond.

Of the core scenario studies in Table 5.2, the most detailed description of human well-being outcomes under the different scenario types is again provided by the MA. The other core studies assessed in this chapter talk more generally about good quality of life in terms of economic development (Nakicenovic *et al*., 2000; WWF-AfDB, 2015; UNEP, 2016) or specific health-related concerns, such as air and water pollution (UNEP, 2007; WWF-AfDB, 2015; UNEP, 2016). For the purposes of this section, the five scenario archetypes are discussed in light of the following human well-being outcomes, building largely on those addressed in the MA (Butler *et al*., 2005): material well-being and poverty reduction (including food, water and energy security), equity, health, security and social relations, as well as freedom and choice. Where possible, details about each of these human well-being components were extracted from the core scenarios studies (presented in Table 5.2) and supplemented with relevant information from local or regional-scale studies making use of these scenario archetypes. Overall scenario trends for Africa are summarised in Table 5.5, with the acknowledgement that continent-wide trends may mask heterogeneity in outcomes for different regions, groups of people, or aspects of the human well-being component.

Table 5.5: Summary of well-being trajectories in scenario archetypes for Africa. Arrows indicate an increase (↗), decrease (↘), or no change (→) in the human well-being component under each scenario type, relative to the present. Within a cell, arrows represent the main scenario reports in the following order: IPCC; MA; GEO4; WWF/GEO6. If a report does not cover an archetype, this is symbolised by '0', whilst if a report does not explicitly address a specific element, it is indicated by an 'X'. The colour of the cell indicates the overall trend across the reports, where green indicates an overall increase, orange indicates an overall decrease, purple indicates contradictory trends, and no colour indicates no overall change.

HUMAN WELL-BEING COMPONENT	FORTRESS WORLD				MARKET FORCES				POLICY REFORM				LOCAL SUSTAINABILITY				REGIONAL SUSTAINABILITY			
	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF
Material well-being & poverty reduction	→	↘	↘	O	↗	O	↗	→	O	↗	↗	↗	→	↗	O	→	↗	↗	↗	↗
Equity	↘	↘	↘	O	↗	O	→	↘	O	↗	↗	→	→	↗	O	→	↗	→	↗	→
Health	↘	↘	↘	O	↗	O	→	→	O	↗	↗	→	→	→	O	→	↗	→	↗	↗
Security & social relations	↘	↘	↘	O	→	O	→	↘	O	↗	→	→	→	↗	O	↘	→	→	↗	↗
Freedom & choice	↘	↘	↘	O	↗	O	↗	→	O	→	→	→	↗	↗	O	→	↗	↗	↗	↗

↗ Increase ↘ Decrease → No change O Not covered X Not addressed
Overall increase in trends Overall decrease in trends Contradictory trends No overall change

5.6.1. Material well-being and poverty reduction

Under three of the five scenario archetypes (*Market Forces*, *Policy Reform* and *Regional Sustainability*), global trade, technological advances and large-scale resource extraction lead to a general increase in material well-being and poverty reduction (Nakicenovic *et al.*, 2000; MA, 2005; UNEP, 2007). Energy security is met in all three these archetypes; in the case of *Regional Sustainability*, through large-scale renewable energy projects in places like the Sahel (Lambin *et al.*, 2014). However, in this scenario, there is also a risk of rising unemployment due to increasingly affordable robotization in the workplace (MA, 2005). Globally, food security is also met under these archetypes, though the *Market Forces* archetype initially sees a reduction in food security for Africa's rural population due to a focus on the production of cash crops (WWF-AfDB, 2015; UNEP, 2016) and the impacts of climate change (Shah *et al.*, 2008). This imbalance is potentially addressed in the longer-term through partnerships between government, business and communities.

Climate change remains a challenge under most archetypes. In both the *Regional Sustainability* and *Market Forces* scenarios, climate change is predicted to have negative impacts on agricultural production and farm incomes in many parts of the continent (Boko *et al.*, 2007), including low-lying areas in East Africa where the majority of Kenya's farmlands are situated (Mulwa *et al.*, 2016). In the *Local Sustainability* scenario archetype, diverse, climate-smart agricultural practices and localised water and renewable energy infrastructure developments see an improvement in livelihood, food, water, and energy security at the household level (Lambin *et al.*, 2014; WWF-AfDB, 2015; UNEP, 2016). This archetype relies on local (not global) solutions for sustainability challenges and is characterised by intermediate levels of economic growth and population increase (Nakicenovic, 2000).

The only scenario archetype in which material well-being declines and poverty increases for most people in Africa is the *Fortress World* archetype, where the population grows rapidly and food production cannot always keep pace (MA, 2005; UNEP, 2007). In this scenario, Fischer *et al.* (2005) predict a net decrease in cereal production capacity of up to 12% across sub-Saharan Africa. Due to fragmented and regionalized economies, per capita growth rate and advances in technology are slow (Nakicenovic, 2000). The elite consumes most of the goods and services, while global trade collapses and poverty traps are reinforced (MA, 2005). Furthermore, changes in climate and the resulting shifts in harvestable commodities (like cultivated Rooibos tea in South Africa and Argan trees in Morocco) add to the pressures experienced by small and resource-poor farmers (Lötter *et al.*, 2014; Alba-Sánchez *et al.*, 2015).

5.6.2. Equity

Equity shows a mixed pattern across the five scenario archetypes, with inequality clearly decreasing in the *Policy Reform* and *Regional Sustainability* archetypes (Nakicenovic, 2000; UNEP, 2007). In the former archetype, institutions that promote equity and fairness are supported, and property rights are strengthened (MA, 2005). In the latter, inequality is reduced through a change in economic structures towards a service and information economy, coupled with cleaner and more resource-efficient technologies. These developments lead to the growth of the middle class in Africa (WWF-AfDB, 2015; UNEP, 2016).

In the *Market Forces* archetype, inequality in Africa is suggested to increase initially, as economic development occurs in patches and leaves some places behind. However, in the longer term, a focus on inclusive and green growth leads to improved development of local communities, reducing inequality to some extent (WWF-AfDB, 2015; UNEP, 2016). A different picture emerges in the *Local*

Sustainability archetype, which describes a more immediate decrease in inequality—especially at the community level—due to a reduction in global trade and a stronger focus on local production and consumption of goods (MA, 2005). However, the situation in Africa is more mixed, because not all community members benefit equally from local innovations and practices such as eco-tourism. This could lead to pockets of conflict and issues like poaching (WWF-AfDB, 2015; UNEP, 2016).

In contrast, inequality widens across the board in the *Fortress World* archetype, due to protectionist, region-centred policies and trade, restricted migration, and faltering education systems in poorer countries (MA, 2005; UNEP, 2007). There are high levels of cultural pluralism, and different regions deal with challenges of poverty differently: some choose a welfare approach, others move toward leaner governments that do not support the poor (Nakicenovic, 2000).

5.6.3. Health

In most of the scenarios, health improves on many fronts: greater overall affluence, improved public health systems and nutrition, as well as technological advances result in longer lifespans and better health in the *Market Forces*, *Policy Reform* and *Regional Sustainability* archetypes (Nakicenovic, 2000; MA, 2005). However, pollution remains a challenge, especially in the *Market Forces* and *Policy Reform* archetypes, where industrial and agricultural intensification in Africa result in water and air pollution in rural areas, as well as in poor urban communities (UNEP, 2007; SADC, 2008; WWF-AfDB, 2015; UNEP, 2016). Under *Market Forces*, expansion of mining and unregulated coal power generation in the Gariep river basin of South Africa causes high levels of water pollution in urban areas (Bohensky, 2008), and climate change plus increased phosphate loads lead to water quality declines along the Tunisian coast (Lamon *et al.*, 2014). Furthermore, changing climate patterns under high-emissions scenarios like *Market Forces* lead to changes in the distribution of infectious disease vectors such as ticks and mosquitoes. In the case of ticks, the evidence suggests range expansions across Africa for multiple species (Cumming *et al.*, 2006). The future distribution of malaria vectors like *Anopheles arabiensis*, on the other hand, is predicted to be significantly reduced on the continent, especially in western and central Africa (Drake *et al.*, 2014; Box 5.6).

Pollution challenges are also experienced in the *Local Sustainability* archetype, mainly because of poorly enforced national environmental and health standards (due to a focus on local governance in this scenario, and consequently a lack of national or regional oversight and coordination). Here, poor enforcement may result in the dumping of waste into watercourses and increased mortalities from water-borne diseases (Bohensky, 2008). Only in the *Regional Sustainability* storyline is pollution sufficiently curbed by advances in technology (Nakicenovic, 2000; MA, 2005; UNEP, 2007). However, technology is a double-edged sword, resulting in health improvements such as better vaccines and gene therapy, but also increased risks such as designer drugs and the intentional, harmful spread of disease as a form of biowarfare. In addition, this scenario sees a rise in the prevalence of obesity and diabetes, which in turn increases some forms of cancer (MA, 2005).

Other health risks include the increased outbreak of zoonotic diseases, especially in the *Fortress World* scenario, where people are forced into close contact with wildlife as they search for natural resources to support their dwindling livelihoods (MA, 2005). For example, the incidence of human monkeypox (which can cause serious smallpox-like illness and is transmitted mainly via rodents) is projected to increase in areas like the eastern Democratic Republic of the Congo (Thomassen *et al.*, 2013). In addition, climate change under the *Fortress World* scenario is likely to increase the distribution and transmission of lymphatic filariasis (elephantiasis) across Africa (Slater *et al.*, 2012) (Box 5.6). Overall, *Fortress World* sees much-reduced health conditions for people in Africa, and infant and maternal mortality rates remain high. Food insecurity leads to substandard nutrition in the continent's poor countries, resulting in chronic poor health for many people (Fischer *et al.*, 2005; UNEP, 2007; Lambin *et al.*, 2014).

5.6.4. Security and social relations

Similarly, there is a rapid decline in security and social relations under the *Fortress World* archetype. Due to widening inequalities, worsening poverty, and general mistrust, social relations deteriorate at all scales, from local to international (MA, 2005; UNEP, 2007). Civil society dwindles, and there is the potential for "barbarization", i.e., widespread corruption and lawlessness. Countries in which order is maintained are paranoid about border security and restricting migration, fuelling prejudice and discrimination. There is a higher likelihood of terrorism, as the marginalised rebel against unjust systems (MA, 2005). But the tensions between rich and poor do not only play out at the international scale. Also within countries or regions like the Sahel and southern Africa, urban areas experience a constant flow of migrants from poor rural areas, resulting in rapid and unplanned growth of cities and the deterioration of living conditions for the non-elite (SADC, 2008 Lambin *et al.*, 2014).

In sharp contrast, under the *Regional Sustainability* archetype, social relations and security in Africa are well maintained, facilitated by technology (Nakicenovic, 2000; MA, 2005; UNEP, 2007). There is a move towards civil society engagement, democratization and a strong judiciary. But technology also comes at a price, where real human interaction may suffer as a consequence of digital and virtual relationships. Globally, advances such as human cloning and "designer babies" may cause fundamental moral and ethical conflicts, as well as behaviour changes (MA, 2005).

In many of the scenarios (*Market Forces, Policy Reform* and *Regional Sustainability*), borders are softened and migration and movement of people become freer. However, there are pockets of unrest and conflict in both the *Policy Reform* and *Market Forces* storylines, mainly centred on access to resources (WWF-AfDB, 2015; UNEP, 2016). In the former archetype, for example, African smallholders and artisanal fishers lose their lands and jobs to large-scale commercial agriculture and fisheries. This may lead to social conflict and even local armed rebellion in some places (Lambin *et al.*, 2014). Under the *Market Forces* archetype, exploitation of African resources by foreign companies in the immediate future could lead to conflict. There is potential for unplanned and unserviced settlements to spring up around concentrated hubs of economic activity (e.g., mines), which means companies will increase security to protect their assets. The surrounding communities are forced to turn to local ecosystems for goods and services that are not provided by the companies or government, thus adding to local environmental degradation. Conflicts over access to resources may lead to illegal extraction or poaching by community members, and a general increase in crime and political instability. The key to turning this picture around in the longer term is through inclusive development of local communities (WWF-AfDB, 2015; UNEP, 2016).

Finally, the *Local Sustainability* archetype shows a mixed picture, with strong civil societies that support local governments, and a greater self-sufficiency of local communities, which reduces regional disputes, civil war and terrorism (MA, 2005). On the other hand, the emphasis on local decision-making poses a risk for international governance of common pool resources (WWF-AfDB, 2015; UNEP, 2016), in that a lack of regional planning and implementation may result in natural resource degradation over time, and a downward spiral of poverty for rural communities. This may lead to migration from impoverished rural areas to rapidly growing, informal urban settlements, especially by young people and men – leaving women and children behind. These dynamics have a detrimental effect on social cohesion and could culminate in lawlessness and crime (WWF-AfDB, 2015; UNEP, 2016).

5.6.5. Freedom and choice

With the exception of the *Fortress World* scenario in which freedom and choice substantially deteriorate, the other scenario archetypes describe a situation in which freedom and choice generally improve, but with some caveats. The *Market Forces* scenario sets out the greatest improvements in terms of freedom and choice globally. Greater affluence, a focus on capacity building, and increased social and cultural interaction in a globalised economy make freedom and choice more palpable (Nakicenovic, 2000; MA, 2005). However, in Africa, as in certain other parts of the world, these freedoms are not as readily experienced, due to unequal economic development across the continent, and foreign hegemony over resources (WWF-AfDB, 2015; UNEP, 2016).

Both the *Policy Reform* and *Regional Sustainability* scenarios raise the possibility of some people being displaced from their lands to make way for large-scale commercial enterprises, resulting in marginalisation, as well as loss of knowledge and cultural identity in these communities (WWF-AfDB, 2015; UNEP, 2016). In the *Regional Sustainability* scenario, farmers and pastoralists may lose access to traditional communal lands in the Sahel region (due to the installation of large solar power plants), resulting in the loss of indigenous knowledge and cultural roots (Lambin *et al.*, 2014). In the *Policy Reform* scenario archetype, there is a risk that fewer and fewer people feel connected to nature and lose the spiritual satisfaction associated with working the land and experiencing natural environments (MA, 2005).

The *Local Sustainability* archetype emphasises freedom and choice at local levels: Local social-ecological experimentation and innovation confers freedoms to community members, and learning about local ecosystem functioning is a priority (Nakicenovic, 2000; MA, 2005; Lambin *et al.*, 2014). But this archetype also describes the risk of increased community autonomy leading to unchecked human rights violations and "othering" in local communities, as well as towards newcomers and migrants, thereby significantly reducing the freedoms, choices and security of vulnerable groups (MA, 2005).

The main risks to the freedom and choice of people in Africa in the *Fortress World* archetype are restrictions on migration, trade and access to resources and education (Nakicenovic, 2000; MA, 2005; UNEP, 2007). These restrictions severely limit the opportunities for a good quality of life. There is also the potential for censorship and control over communication platforms like the internet, reducing the opportunities for free speech and self-expression. Fundamentalism rises in a response to these threats to expression and participation, further limiting freedoms and choices (MA, 2005).

5.6.6. Uncertainties, gaps and research needs

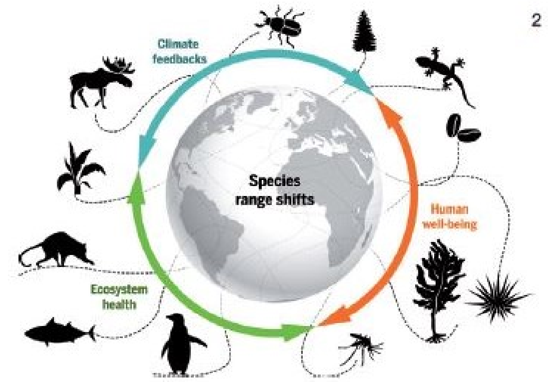
The links between biodiversity, ecosystem services and human well-being are only partly explored in the scenarios assessed in this chapter. Mostly, the scenarios paint general pictures of social-ecological trajectories for Africa, where changes in human well-being are not necessarily directly linked to changes in biodiversity or ecosystem services. With the exception of the MA, human well-being components such as equity, security, or freedom and choice are rarely considered explicitly in the context of environmental change. This lack of detail in the main scenario reports and the papers included in the systematic review points to a lack of research that considers a broad range of human well-being aspects (beyond just material well-being) in future scenarios of Africa's biodiversity and ecosystem services.

Within the existing literature, clearer links have been made between aspects such as natural resource exploitation (like mining and farming) and water or air pollution, which impacts negatively on health (e.g., *Policy Reform*, WWF-AfDB, 2015; UNEP, 2016), or changes in land-use or access to resources and the resulting loss of livelihoods for certain groups of people (e.g., *Market Forces*, WWF-AfDB, 2015; UNEP, 2016). However, even these links are mostly qualitatively described, with very little quantitative modelling of human well-being. The exceptions mainly deal with modelling disease incidence under climate scenarios (Box 5.6), as well as changes in agricultural production or income (e.g., Slater *et al.*, 2012; Mulwa *et al.*, 2016). Compared to certain health impacts and livelihoods, the relationships between human well-being aspects such as equity or security and ecosystem condition are much more difficult to assess or model (Levy *et al.*, 2005; Raudsepp-Hearne *et al.*, 2010). This disconnect may partly explain the overall very positive human well-being outcomes described by *Regional Sustainability* (Table 5.6), even though significant negative impacts on biodiversity and ecosystem services are suggested for Africa under this scenario (WWF-AfDB, 2015; UNEP, 2016).

There is also very little regional specificity when it comes to human well-being in the different scenario studies. This is especially concerning when one considers the large differences in culture, socio-economic conditions and projected climate change impacts between different subregions of Africa - impacts such as water stress and concomitant water quality issues that can lead to a wide range of potential diseases, including childhood diarrhoea, a leading cause of death among African children (UNEP, 2008). The majority of scenarios also outline a tension between urban and rural areas, or the centres of development and the communities "left behind", yet these divergent trajectories are not explored in detail. Future African scenario research should address these gaps to understand differences between areas, along with carefully disaggregating well-being impacts across different groups of people. Because of the high levels of inequality on the African continent, especially in sub-Saharan Africa (Beegle *et al.*, 2016), scenarios of well-being impacts due to environmental change need to take into account the often fine-scale heterogeneity among Africa's population.

Box 5 6 Scenarios of future climate-related health impacts in Africa. Sources: images from 1) Shutterstock; 2) Pecl *et al.* (2017); 3) Shutterstock; 4) *Anopheles arabiensis* by CDC/ James Gathany.

A number of scenario studies assess the potential impacts of climate change on human health in Africa. Climate change scenarios developed by the IPCC are commonly used to model shifts in future distributions of disease vectors such as mosquitoes, tsetse flies and rodents. For example, Drake *et al.* (2014) suggest that the range of *Anopheles arabiensis*, a prominent mosquito species that transmits malaria, will be significantly reduced across Africa under three major climate change scenarios by 2050. These reductions are mainly due to changes in temperature and precipitation that affect the mosquitoes' habitat. Range contractions are expected to be especially extensive in western and central Africa, as well as the western parts of southern Africa. However, much of the Rift Valley region and eastern coastal area of Africa is expected to remain prime habitat for the mosquito, and the models predict some range expansion into currently marginal areas in South Sudan, Angola and South Africa.



In contrast, other diseases are predicted to become more widespread in Africa under future climate scenarios. Lymphatic filariasis (LF), for example, is a disease that may cause the debilitating swelling of extremities, and is also transmitted by mosquitoes. The distribution of LF across the continent is expected to increase under the A2 and B2 IPCC scenarios, mainly driven by increases in human population density (Slater *et al.*, 2012). Similarly, at more regional scales, the monkeypox virus is emerging as an infectious disease of major concern in tropical Africa. It is transmitted by rodents and other mammals, and can cause a serious smallpox-like illness in humans. Future climate change scenarios predict an eastward shift of monkeypox occurrence from the western parts of central Africa into regions where the virus is currently not found, like the eastern Democratic Republic of Congo, and parts of Uganda, Kenya and Tanzania (Thomassen *et al.*, 2013). Again, the main drivers of this shift are climatic, but also include deforestation, as well as human behaviour such as bushmeat hunting.

These studies perform an important function in identifying areas where increased surveillance efforts are needed to detect the emergence of diseases in time, and to prevent their spread. However, only a limited number of drivers can typically be modelled, which may oversimplify the complexity of future scenarios. For example, ecological niche models such as used by Drake *et al.* (2014) to predict the distribution of *A. arabiensis* may fail to take into account demographic and economic changes implicit in future scenarios – changes such as increases in human population density, which may counteract the reductions in malaria predicted by purely climatic changes. These model predictions should therefore be treated as only part of the puzzle, contributing important but incomplete information to the picture of Africa's future.

5.7. Policy implications and options

The assessment presented in this section focuses on key policy processes currently underway in Africa and how they might assist with addressing important development challenges outlined in the scoping report under different scenarios. Table 5.6 presents a general summary of the emerging policy implications based on the five archetypes explored in this chapter, showing the overall trends in key drivers, ecosystem integrity and human well-being outcomes as discussed in sections 5.4–5.6. It is important to keep in mind that these summaries are not predictions of the future, but rather aim to give a sense of the range of plausible futures that could unfold on the continent, given different sets of drivers, management interventions and governance responses and their complex interactions with the environment and society.

Table 5.6: Trends in the drivers of biodiversity loss, biodiversity, nature's contributions to the people and human well-being under each of the archetypes used to categorise the scenarios surveyed in Africa, with response options that could help to minimise some of the negative drivers towards achieving targets. This table summarises the results of the assessment of different drivers (Table 5.3), biodiversity and nature's contributions to people (Table 5.4), as well as dimensions of human well-being trajectories (Table 5.5) under different scenario archetypes for Africa (Box 5.2). The arrows indicate an increase (↗), decrease (↘), or no change (→) under each of the different categories for each scenario type into the future. The colour of the cell indicates the overall impact of the results across the reports, where green indicates an overall positive impact, orange indicates overall negative impact, purple indicates contradictory trends, and no colour indicates no overall change/impact. The table shows that the impacts of all drivers are expected to increase under all scenarios, except for mixed results linked to regional and global resource demand under local sustainability. The final column outlines potential governance responses based on Table 6.2 that could help to navigate towards improving biodiversity, nature's contributions to people and human well-being by addressing particular negative drivers in each of the scenario archetypes. The responses are not exhaustive, but showcase examples of how scenario exercises can help to elucidate policy options for achieving desirable outcomes.

ARCHE-TYPES	SUMMARY DESCRIPTION	Drivers	Biodiversity	Nature's contributions to people	Human well-being	Potential governance responses/ Emerging implications
FORTRESS WORLD	• Expansive agriculture drives habitat loss, soil erosion and water pollution and low crop yields. This results in the largest relative habitat loss by 2050, undermining provisioning services, and water stress increases dramatically • Ecosystem services will be reduced in significant proportion and hence nature's contributions to people will be at its lowest level • The intrinsic vulnerabilities of already fragmented habitat are worsened through increasing poverty levels and the over-exploitation of ecosystems all of which compromise human well-being • Industrialisation leads to increasing disparity between the poor and the rich	↑	↓	↓	↓	• Promote investments in environmental friendly technologies (e.g. water pollution) • Strong environmental and social regulations are enforced • Human rights based approaches are enforced to meet needs and reduce inequalities

ARCHE-TYPES	SUMMARY DESCRIPTION	Drivers	Biodiversity	Nature's contributions to people	Human well-being	Potential governance responses/ Emerging implications
MARKET FORCES	• Human well-being increases under free trade but distribution of benefits may not be equal • Habitat loss and biodiversity may increase in the long term which could compromise human well-being • Economic growth may contribute towards recovery of degraded ecosystems and improved livelihoods	↑	↓	↓	⤢	• Regulatory frameworks e.g. social safety nets to ensure basic needs are met • Build government capacity to legislate and enforce community sensitive environmental policies • Ensure that value of ecosystems are incorporated into environmental management plans (Private and Public sector)
POLICY REFORM	• Export driven growth strains economic diversification, with protected areas increasing • Outside of protected areas, the strong dependence on a few natural resources leads to degradation of ecosystems • Under low population pressure, human well-being appears to improve though it may be compromised in the long term by degradation of ecosystem services • Loss of species and habitats outside protected areas due to agricultural expansion and infrastructural development would reduce ecosytem services and nature's contributions to people	↑	↓	↓	↑	• Stimulate capacity, livelihoods and job creation in diverse sectors outside of primary industries • Ensure effective implementation of community based conservation, and ecotourism (e.g. Community-based natural resource management principles are implemented) • Ensure that private and public sector developments (e.g. industrial, agricultural) adhere to environmental and social standards
LOCAL SUSTAINA-BILITY	• Social equity and welfare are prioritised which result in improved human well-being • Local sustainable agriculture ensures 'sustainability hotspots', but beyond these areas, degradation continues and habitats are fragmented • The uncoordinated nature of local agricultural choices may undermine regional ecological integrity in the longer-term • There is a high likelihood for retention of indigenous local knowledge as a result of its particular focus on local scales • Haphazard growth may result in conflicts and numerous environmental crimes while in other areas innovative local adaptation emerges	↑	↓	⤢	→	• Learn from sustainability bright spots and best practice and promote linkages and exchange of knowledge (e.g. Indigenous local knowledge for sustainable development) • Promote markets for sustainably produced goods at local and subregional level
REGIONAL SUSTAINA-BILITY	• More effective governance allows for more effective environmental regulation, increasing protected area function and coverage, and allowing for improved transboundary environmental cooperation • Conservation efforts are directed at sustainable use and maintenance of ecosystem services, rather than species protection • Technological innovation drives landscape homogenisation and potential food security with overall increase in human well-being	↑	↓	⤢	↑	• Leverage regional strength to access and develop sustainable global markets without compromising local ecosystem integrity • Build subregional resilience to shocks (e.g. climate related disasters) by maintaining global connections (e.g. markets, partnerships, resources, innovations)

↓ Decreasing ⤢ Mixed trends ↑ Increasing → Current trend continues

Issues related to the food-water-energy nexus, land degradation, and invasive species have many features in common, including complex combinations of drivers, interactions across local to global scales, thresholds and lag effects, which make the development, alignment and implementation of policies difficult. Furthermore, issues such as poverty alleviation, biodiversity loss and food production require collective agreements for concerted action and governance across scales that go beyond political boundaries and individual national benefit (UNEP, 2009). The Ecological Futures report led by the WWF and AfDB in 2015 explores four different scenarios of social-ecological development in Africa and outlines their key policy implications (WWF-AfDB, 2015). These scenarios were derived from a variety of multi-stakeholder and multi-sector participatory workshops and include visions aligned with key policy processes in Africa linked to NEPAD, the African Development Bank, and the United Nations Economic Commission for Africa. The resulting co-developed scenarios also underpin the GEO6 Regional Assessment (UNEP, 2016). Given their utility for understanding the potential impacts of various policies and interventions on the contribution of biodiversity and ecosystem services for sustaining the economy, livelihoods, food, water and energy security and good quality of life specifically in Africa, they are drawn on heavily in this section.

The WWF report relates to how nations and regions might co-design and align policies related to three key issues in Africa: i) economic activities (the location and intensity of agricultural and extractive and manufacturing activities); ii) human settlements (the distribution and consumptive demands of human settlements); and iii) infrastructure (the nature and extent of infrastructure that is needed to support economic activities, consumption demands, conservation activities (e.g., waste water treatment), coupled with the supply chains and trade systems that are needed to sustain the infrastructure). The location and intensity of each of these three issues are influenced by the development trajectory the continent and different countries take, and the governance mechanisms established to manage development. The scenarios specifically explore trade-offs associated with lock-in behaviours and dependencies that large-scale infrastructure projects aimed at addressing the infrastructure deficit on the continent might entail. The intensity and scale of impact of key indirect and direct drivers (see Section 5.4) in different regions and countries will alter the types of policies and governance processes (see Chapter 6) that are required to mediate these intersecting issues in Africa.

In the remainder of this section, we assess the likelihood of achieving key development targets in Africa under each of the scenario archetypes and summarise these in Table 5.7. The foundation of our analysis is the African Union Agenda 2063 aspirations and how they align with the implementation of the SDGs, the Aichi Biodiversity Targets (ABTs), and the goals of other policy frameworks such as the Sendai Framework for Disaster Risk Reduction and climate targets negotiated through the IPCC and other associated declarations.

5.7.1. Food-water-energy nexus (SDGs 2, 6, 7, 12; ABTs 6, 7; Agenda 2063 10, 17)

An important aspiration for a sustainable and prosperous Africa is that citizens are healthy and well-nourished. Policies aligned with increasing and modernizing agricultural production and access, including sustainable fisheries are best met under *Policy Reform* and *Regional Sustainability* archetypes (MA, 2005; WWF-AfDB, 2015; UNEP, 2016) while least likely under conditions of *Fortress World* (WWF-AfDB, 2015) with little change being seen through conflicting policies associated with a *Market Forces*-type future (MA, 2005; Lambin *et al.*, 2014). Achieving a goal of zero hunger, however, is unlikely without compromising water quantity and quality (see section 5.8 on trade-offs).

Clean water and sanitation for Africans is best met under conditions of *Local Sustainability* (WWF-AfDB, 2015; UNEP, 2016) and least likely under policies associated especially with *Market forces* and *Fortress World* (MA, 2005; Bohensky *et al.*, 2006; van Vliet *et al.*, 2013; Niang *et al.*, 2014 - RCP8.5; WWF-AfDB, 2015; UNEP, 2016). Affordable and clean energy provision is most likely under the *Regional Sustainability* and *Local Sustainability* archetypes (Lambin *et al.*, 2014; WWF-AfDB, 2015; UNEP, 2016). Trade-offs associated with climate and energy security are best addressed through climate action under *Regional Sustainability*, while the least climate action is associated with the *Fortress World*-type future (O'Neill *et al.*, 2014).

It is important to understand how issues related to the food-water-energy nexus are also linked to responsible consumption and production, mediated through strong institutions and effective governance. Such policies and the institutions necessary to implement them are most prevalent under *Regional Sustainability*, and least developed under *Fortress World* (Nakicenovic, 2000; MA, 2005; Bohensky *et al.*, 2006). Overall, policies associated with the *Regional Sustainability* archetype are most proactive and supported by good institutions and governance arrangements, and are therefore most likely to achieve aspirations and goals[1] stipulated in global and regional policies related to food, water and energy (Table 5.7).

5.7.2. Land degradation (SDGs 12, 15; ABTs 5, 7, 11, 14; Agenda 2063 17)

Land degradation and associated negative impacts on biodiversity and NCP in Africa are the highest under *Fortress World* (Nakicenovic, 2000; MA, 2005; UNEP, 2007; van Vliet *et al.*, 2013; WWF-AfDB, 2015), while policies associated with maintaining intact landscapes outside protected areas are the least effective under *Policy Reform* (Biggs *et al.*, 2008; Alcamo *et al.*, 2011; UNEP, 2016). Interventions associated with *Regional Sustainability*, *Local Sustainability* and *Market Forces* contribute the most to the goal of halving the rate of loss of biodiversity and preventing extinctions (Nakicenovic, 2000; UNEP, 2016). The *Local Sustainability* archetype potentially yields the best outcomes in terms of sustainable cities and communities (UNEP, 2016).

5.7.3. Invasive species (SDGs 15; ABTs 5, 9, 14)

Policies relating to invasive species control and active restoration of landscapes are most strongly addressed within the *Local Sustainability* scenarios, with the prevention of invasive species least likely under *Policy Reform* and *Fortress World* (MA, 2005; UNEP, 2016). Where eradication is impossible, exploiting invasive species as a resource is a potential management option. For example, the water hyacinth (*Eichhornia crassipes*), a water plant threatening freshwater ecosystem services more or less worldwide, could serve as a potential bioenergy resource in Malawi (Kriticos *et al.*, 2016).

5.7.4. Catchment to coast (SDGs 6, 14)

Achieving policies associated with restoring and maintaining healthy aquatic systems are best realised *Policy Reform* (MA, 2005; UNEP, 2016) and *Local Sustainability,* which has a strong focus on sustainable use and management of water resources for development (Nakicenovic *et al.*, 2000; MA, 2005; Lambin *et al.*, 2014; WWF-AfDB, 2015). Waterborne diseases are expected to increase under *Fortress World* (UNEP, 2007), with pollution of water sources, mainly from untreated wastewater being of concern across all scenarios (MA, 2005; UNEP, 2007; UNEP, 2016).

5.7.5. Conservation and sustainable use (SDGs 14–15; ABTs 5–7, 11–12)

The network of protected areas is increased under *Policy Reform* (UNEP, 2016), which helps conserve biodiversity within protected areas and buffer zones; however under this same scenario, biodiversity decreases outside of protected areas (UNEP, 2016; Biggs *et al.*, 2008; Alcamo *et al.*, 2011) as terrestrial resources are not used sustainably. The same trend is seen under *Fortress World* (Nakicenovic *et al.*, 2000; MA, 2005; van Vliet *et al.*, 2013), where unsustainable practices increase the most. Fisheries and marine resources however recover under *Policy Reform* due to consolidation of investment into terrestrial resource extraction. Resources are used most sustainably under the *Regional Sustainability* scenario.

5.7.6. Resilience in a changing world (SDGs 11, 13, 15; ABT 15; Agenda 2063 7.5)

Africa's vulnerability to climate change and the importance of moving towards ecologically sustainable development trajectories is widely recognised (AMCEN, 2013; van der Leemputte, 2016; Nakicenovic *et al.*, 2000). Climate change is predicted to have far-reaching consequences under all scenarios, especially with regard to increasing pressures on water-stressed catchments, land degradation and desertification, and the frequency and severity of natural hazards and extreme weather events, as well as changing species ranges and abundances in Africa. Restoration of ecosystems to enhance their resilience to future uncertainty and surprise linked to a changing climate does not feature strongly under any of the scenarios. It is best addressed under the *Regional Sustainability* scenario (UNEP, 2007; MA, 2005), while none of the other scenarios emphasise policies and actions related to ecological restoration (Nakicenovic *et al.*, 2000; Lambin *et al.*, 2014; WWF-AfDB, 2015). *Local Sustainability and Regional Sustainability* focus on reducing the vulnerability and enhancing the resilience of cities (MA, 2005; UNEP, 2016; Lambin *et al.*, 2014). *Fortress World* shows the most limited climate action, especially with regards to boosting the resilience of cities (MA, 2005; UNEP, 2007; van Vliet *et al.*, 2013; Niang *et al.*, 2014), followed by *Market Forces* (WWF-AfDB, 2015; UNEP, 2016). Few resources are channelled into activities that enhance climate change adaptation and resilience except under *Policy Reform* and *Regional Sustainability.*

5.7.7. Governance and institutions (SDG 16; ABTs 2, 3; Agenda 2063 17)

To meet the goals, targets and aspirations for a prosperous Africa, there needs to be good governance mechanisms and strong institutions to support the various policies driving development. These conditions are best met under the *Regional Sustainability* archetype. In addition, addressing incentives and mainstreaming biodiversity and NCP into decision-making processes is key to achieving many of the Convention on Biological Diversity targets. These are both considered and implemented under *Regional Sustainability*, while *Market Forces* and *Policy Reform* also implement actions to better integrate NCP into development decisions (Nakicenovic *et al.*, 2000). In contrast, *Fortress World* type futures do not formally recognise NCP as important contributions for development (Bohensky *et al.*, 2006; Visconti *et al.*, 2011; Lambin *et al.*, 2014).

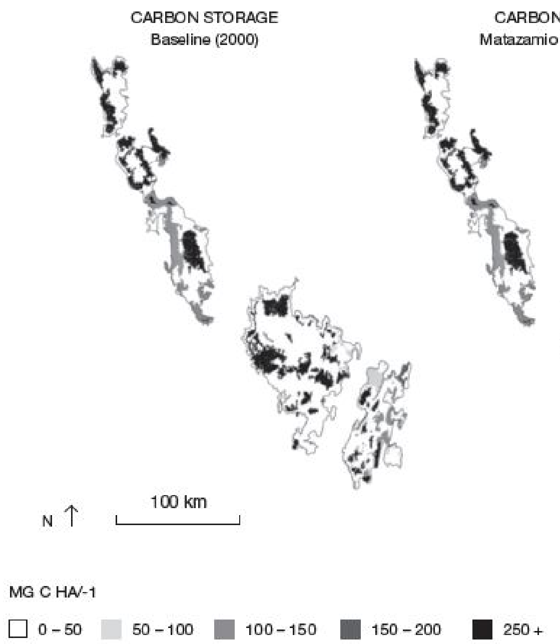
Education on sustainable consumption and production is a feature of *Market Forces* and *Regional Sustainability* futures (Nakicenovic *et al.*, 2000, UNEP, 2007), while this is not a feature of *Fortress World* (Bohensky *et al.*, 2006; UNEP, 2007; Visconti *et al.*, 2011; Lambin *et al.*, 2014). Successful examples where efforts have been taken to mainstream nature and NCP into decision-making using scenario analyses fall under the *Regional Sustainability* archetype (Box 5.7).

Box 5 7 Scenario analyses for policy impact at national scale – Eastern Arc Mountains, Tanzania. Source: image from Swetnam *et al.* (2011).

A case study in the Eastern Arc Mountains, Tanzania (Fisher *et al.*, 2011; Swetnam *et al.*, 2011) demonstrates how the co-development of scenarios of ecosystem services with multiple stakeholders can be used to inform a variety of policy decisions about land use at local, sub-national and national scales. The study assessed the impacts of land-use change on a variety of ecosystem services important for local livelihoods, including carbon storage and sequestration, biodiversity, water yield, firewood, building materials, food, and provision of wood for charcoal production. The study aimed to provide information for upscaling market mechanisms to maintain ecosystem services, answering questions such as: Why are REDD (Reducing Emissions from Deforestation and forest Degradation) and PWS (Payments for Watershed Services) policies needed?"; "Where are REDD pilots most likely to be economically viable compared with other land-use choices?"; and "Where does conservation make the most sense in terms of the net social benefits and costs across a range of services and land uses?".

One outcome of the scenario development was their use as an input for the carbon modelling. The scenarios showed policymakers what might happen to Tanzanian forests in the future, and the implications for multiple ecosystem services. The difference in the future carbon storage in the Kama Kawaida scenario compared to the Matazamio Mazuri scenario showed the additional carbon "saved." This helped identify areas that could be candidates for payment under REDD+ and voluntary carbon projects. This work also developed new insights on the contribution of ecosystem services to a range of beneficiaries – from the global community to poor, local, rural communities.

The case study also demonstrates how co-developing scenarios through extensive stakeholder input and participation through policy reviews, interviews and workshops, increases the salience and legitimacy of the scenario options. The scenario development process created a framework for exploring how driving factors - such as policy shifts and their associated socio-economic effects (e.g. population growth) – might change in the future. The scenarios represented possible futures that were grounded in policy and practical realities in Tanzania, increasing their credibility with stakeholders.



Changes in the spatial distribution of carbon storage under baseline conditions versus two future scenarios in the Eastern Arc Mountains of Tanzania.

Table 5.7: Synthesis of the likelihood of achieving key policy targets, Agenda 2063 of the African Union Aspirations for a prosperous Africa, Sustainable Development Goals and targets and Aichi Biodiversity Targets, under different scenario archetypes in Africa. This table shows the summary of the assessment (Section 5.7) that seeks to understand the likelihood of achieving aligned Agenda 2063 Aspirations (1st column), Aichi Biodiversity Targets (2nd column) and Sustainable Development Goals (3rd column) in Africa under the five different scenario archetypes (See Box 5.2, Section 5.3, Table 5.1 and Table 5.2 for more information). The colour of the cell indicates a synthesis of the overall trends found in the assessment under different scenario options where green indicates an overall increase in the likelihood of achieving the desired policies (Agenda 2063 Aspirations, Aichi Biodiversity Targets and Sustainable Development Goals), purple indicates contradictory trends found (i.e., some reports in the assessment mentioned an increase in the likelihood of achieving certain outcomes, while others reported a decrease), and orange indicates an overall decrease in the likelihood of achieving the policy outcomes. No colour in the cells represents a lack of robust information on these issues in the reports/studies. This table highlights that while there are many trade-offs to consider under each possible future scenario, there are multiple synergies and policy alignments where more desirable options for sustainable and equitable development are feasible. It also highlights that conditions and policies under a 'Fortress World' (see Box 5.2 for underlying assumptions) are the least likely to achieve multiple goals and targets and will ultimately result in the inability to deliver on the aspirations of Agenda 2063 for a future we want in Africa. 'Business-as-usual' approaches through reliance on the market forces (MF) and policy reform (PR) offer some options for achieving multiple policy goals, but fail to adequately conserve biodiversity and resulting contributions of nature to human well-being. Conditions under a more 'managed transformation' type of future, through policies and practices aligned with regional sustainability and, to a lesser extent, local sustainability, are shown here to offer a greater likelihood of achieving multiple sustainable and equitable development goals, targets and aspirations. An important message from this table is that while there are more desirable pathways for decision-makers, there is no one scenario option that will achieve all the goals, targets and aspirations. Efforts to co-develop a combination of proactive policies, inclusive and responsible economic tools with a focus on a well-being economy rooted in the conservation and sustainable use of biodiversity, ecosystems and their contributions to people, are key.

POLICY ALIGNMENT			SCENARIO ARCHETYPES				
			Fortress-based	Business as usual		Managed transition	
Agenda 2063 Goals	Aichi Biodiversity Targets	SDGs and Targets	FW	MF	PR	LS	RS
3 Healthy, well-nourished citizens	14 Ecosystem services	**1 No poverty** (Target 1.4)	orange	purple	green	green	green
		2 Zero hunger (Target 2.3)	purple	green	green	green	green
		3 Good health and well-being (Target 3.3)	orange		orange		
		5 Gender equality (Target 5.A)				green	
5 Modern agriculture for increased productivity and production	7 Sustainable agriculture, aquaculture and forestry	**2 Zero hunger** (Target 2.3, 2.4, 2.A)	purple	green	green	green	green
		12 Responsible consumption & production (Target 12.2, 12.3)	orange	orange	orange		green
		15 Life on land (Target 15.2, 15.B)	orange	purple	orange		purple
6 Blue ocean economy for accelerated growth	6 Sustainable management of aquatic living sources	**2 Zero hunger** (Target 2.3)	orange	green	green	purple	purple
		14 Life below water (Target 14.2, 14.4, 14.7, 14.B, 14.C)	orange	orange	green	purple	orange
7.1 Sustainable natural resource management	8 Pollution reduced	**3 Good health & well-being** (Target 3.9, 3.11)	orange	orange	purple	orange	purple
		6 Clean water & sanitation (Target 6.3)	orange	orange	orange	orange	purple
		11 Sustainable cities & communities (Target 11.6, 11.8)	orange	orange	orange	orange	orange
		12 Responsible consumption & production (Target 12.4)	orange	orange	orange	green	orange
		14 Life below water (Target 14.C)	orange		green		
	9 Invasive alien species prevented and controlled	**15 Life on land** (Target 15.8)	orange	orange	orange		green

POLICY ALIGNMENT				SCENARIO ARCHETYPES				
				Fortress-based	Business as usual		Managed transition	
Agenda 2063 Goals	Aichi Biodiversity Targets		SDGs and Targets	FW	MF	PR	LS	RS
7.2 Biodiversity conservation, genetic resources and ecosystems	13	Safeguarding genetic diversity	2 **Zero hunger** (Target 2.5)					
			15 **Life on land** (Target 15.6)					
	5	Habitat loss halved or reduced	14 **Life below water** (Target 14.C)					
			15 **Life on land** (Target 15.1, 15.2, 15.5)					
	12	Reducing risk of extinction	15 **Life on land** (Target 15.5, 15.7, 15.12)					
			16 **Peace, justice & strong institutions** (Target 16.4)					
	11	Protected Areas	8 **Decent work and economic growth** (Targets 8.3, 8.9)					
			11 **Sustainable cities & communities** (Target 11.4)					
			14 **Life below water** (Target 14.2, 14.5)					
			15 **Life on land** (Target 15.4)					
7.3 Sustainable production and consumption patterns	4	Sustainable production and consumption	6 **Clean water & sanitation** (Target 6.4)					
			9 **Industry, innovation & infrastructure** (Target 9.4)					
			11 **Sustainable cities & communities** (Target 11.6, 11.A)					
			12 **Responsible consumption & production** (Target 12.2-12.7)					
			14 **Life below water** (Target 14.10)					
	1, 2	Awareness of biodiversity increased & Biodiversity values integrated	4 **Quality education** (Target 4.1, 4.7)					
			11 **Sustainable cities & communities** (Target 11.7)					
			12 **Responsible consumption & production** (Target 12.8)					
			13 **Climate action** (Target 13.3)					
			15 **Life on land** (Target 15.9)					
7.4 Water security	14	Ecosystem services	1 **No poverty** (Target 1.4)					
			5 **Gender equality** (Target 5.A)					
			6 **Clean water & sanitation** (Target 6.1-6.8)					
			15 **Life on land** (Target 15.4)					
7.5 Climate resilience and natural disasters preparation and prevention	15	Ecosystem restoration and resilience	11 **Sustainable cities & communities** (Target 11.5, 11.9)					
			13 **Climate action** (Target 13.1)					
			15 **Life on land** (Target 15.1, 15.3, 15.4)					
	10	Ecosystems vulnerable to climate change	1 **No poverty** (Target 1.5)					
			13 **Climate action** (Target 13.2)					
			14 **Life below water** (Target 14.2, 14.3)					
7.6 Renewable energy			7 **Affordable & clean energy** (Target 7.1-7.5)					
			9 **Industry, innovation & infrastructure** (Target 9.4, 9.A)					

5.8. Trade-offs, Tipping Points and Tele-coupling

The linkages and interactions between drivers, biodiversity, NCP, human well-being and policy responses are critical to understanding future trajectories of change across the African continent. Some of these interactions are reasonably predictable and follow established understanding of cause-effect relationships. Such interactions are typically built into scenario storylines and models and underlie much of the discussion in the previous sections. However, other interactions are less predictable, less well understood, and may be difficult to plan for or respond to. Such interactions are generally poorly considered in scenario storylines. This section discusses three such interactions, namely trade-offs, tipping points and tele-coupling, and provides an assessment of each of these under the five key archetypes considered in this chapter.

5.8.1. Trade-offs

A trade-off refers to a situation where an improvement in the status of one aspect of the environment or of human well-being is necessarily associated with a decline in or loss of another aspect. Trade-offs are the opposite of synergies or "win-win" outcomes, where the enhancement of one desirable outcome leads to enhancement of another. Trade-offs characterise most complex systems and are important to consider when making decisions that aim to improve environmental and/or socio-economic outcomes. The scenarios studies considered in this assessment generally do not explicitly consider trade-offs, especially not between different human well-being outcomes. Nevertheless, a number of trade-offs can be anticipated based on the key drivers, and characteristic biodiversity, NCP and human well-being impacts associated with each archetype. Some of these impacts and trade-offs are regulated by policy processes such as Environmental Impact Assessments and Strategic Environmental Assessments; these are not discussed here, but instead addressed in Chapter 6.

Under the *Market Forces* archetype, decentralised local scale investments by multinationals focus on area specific resource extraction, such as large-scale mining and commercial agriculture. Infrastructure, such as roads that are developed to facilitate access and extraction of goods and resources like minerals and food crops, leads to ecological degradation but also enhances the ability of people in these rural areas to access markets and basic facilities. Urban centres associated with investment (typically being port cities such as Dar es Salaam, or mining towns such as Solwezi in Zambia or Tete in Mozambique) in particular act as attractors and there is an increase in migration to these areas. Overall, under this archetype, landscape conversion and extraction takes precedence over sustained ecological function. A similar pattern is evident under the *Policy Reform* archetype. Export-orientated economic growth underpinned by resource extraction results in trades-off of ecological integrity in favour of short-term growth in resource areas rich, including both mineral resource extraction and agricultural production, such as export-focused Cocoa production in Ghana and Côte d'Ivoire. The negative consequences of these trade-offs can be mitigated to some degree by strong centralised governments that recognise the value of protected areas and ensure their continued existence and proclamation of additional protected areas where appropriate. However, broad-scale ecological functioning beyond or outside of protected areas is traded-off in favour of export-orientated development. Furthermore, local level and subsistence needs are traded-off against economies of scale with regards to agricultural production. Under this archetype, smaller farmed land parcels typical of traditional subsistence agriculture, are merged into larger farmed units, resulting in landscape homogenisation, loss of ecosystem service diversity, and greater proportions of people purchasing rather than growing their food.

The *Fortress World* archetype describes a fragmented, self-reliant future that is likely to result in the extensive transformation of local habitats for agricultural production, and the intensive use of ecosystems for resource extraction. Under this archetype, ecological, social and economic sustainability is traded off against national or local sovereignty. The failure to prioritise the development of sectors that hold local or national strategic advantage is likely to drive further ecosystem degradation and biodiversity loss. Under the *Regional Sustainability* archetype, large-scale investments in infrastructure developments (e.g., roads and ports), large-scale agricultural expansion and agricultural development policies, and natural resource extraction (e.g., large-scale fisheries), all result in trade-offs of development over conservation. Infrastructure developments facilitate the exploitation of ecosystems, which erode ecosystem services derived from natural ecosystems. Furthermore, national level development objectives such as sector and industry development (e.g., fisheries such as Tuna in the western Indian Ocean) are prioritised over local level community development, resulting in certain communities remaining or becoming increasingly marginalised. The *Local Sustainability* archetype is characterised by emergent and unplanned local level development. Short-term basic needs relating to resource use and harvesting (such as timber extraction in the DRC forests) are met in favour of long-term sustainable use of natural resources, particularly in areas where there is lack of effective local administration.

5.8.2. Tipping points

A tipping point refers to a set of ecological or social conditions where further perturbation will cause the system to reorganise into a new state with different functional relationships between key system components. This is often accompanied by rapid change, and once a tipping point is crossed, it may be difficult or impossible to return the system to its former state (Biggs *et al.*, 2015b). In the context of scenarios, the bifurcation between two different scenario trajectories is often related to a tipping point or set of tipping points. A database of social and ecological tipping points that affect the provision of ecosystem services, including the drivers and impacts on human well-being, is contained in the Regime Shifts Database[8].

In the *Market Forces* archetype, there are potential tipping points related to local resource degradation and emerging conflict between locals and multinational companies. The focus on commercial agriculture and industry drive increased production but affect water and air quality. Environmental quality thresholds and standards relating to human health may not be met. Biodiversity and conservation tipping points are likely to be breached where illegal harvesting and extraction of resources results in the fragmentation of protected areas, and large-scale declines in species populations. These effects are likely to in turn translate into ecosystem service loss and the breaching critical service provision tipping points. Under the *Policy Reform*, biodiversity and species tipping points are likely to be reached outside of protected areas, with local endemic species being most severely affected. Water quality standards in rural areas are also likely to be breached given the focus on commercial agriculture and mining focus and their high risk of affecting water supplies.

Agricultural expansion under the self-reliant *Fortress World* archetype drives habitat loss, soil erosion and water pollution. The intensive and expansive transformation of landscapes and use of ecosystems will undermine ecosystem services, where the provision of clean water, the quantity of water demand, and level of pollutants are all impacted to the extent that required human health standards are not met. The *Regional Sustainability* archetype highlights potential tipping points relating to biodiversity loss, landscape degradation, and air and water quality. Under the *Local Sustainability* archetype, places with weak and ineffectual local level governance and management could result in broader scale ecological

[8] www.regimeshifts.org

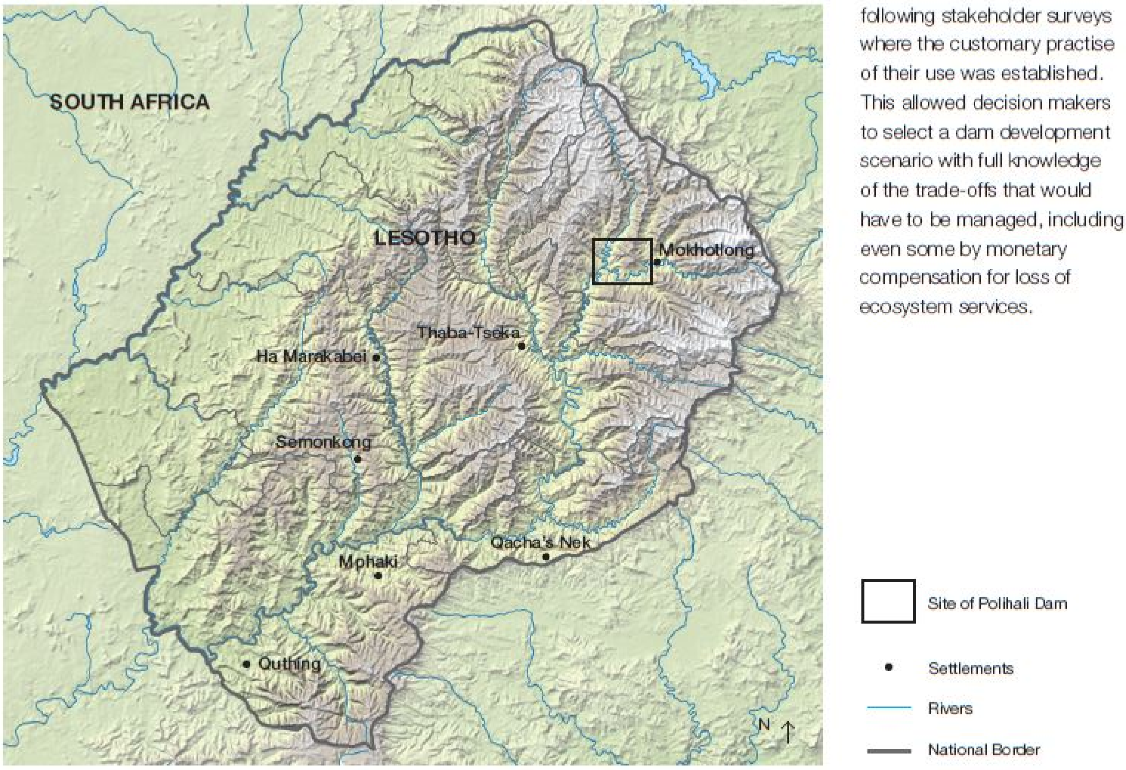
tipping points being exceeded where ecosystems operate over large scales, for example in the management of large river systems.

Box 5 8 **Lesotho Highlands Water Project — scenario integration with thresholds and trade-offs. Source: Lesotho Highlands Water Project — scenario integration with thresholds and trade-offs. Source: Photo by Chris Dickens**

The Lesotho Highlands Water Project is planning to develop a new mega dam in the Lesotho Highlands and policy requires that the downstream people should not be negatively impacted by this construction (LHDA, 2010). Impacts are inevitable. The project has introduced the concept of benefit sharing, where the benefits of the dam as well as the losses will be quantified and mitigation will form part of the planning of the dam. The dam will form part of a transboundary agreement where Lesotho supplies water to South Africa.

Bayesian Network probability modelling was used to assess the flow affected ecosystem services that will be most likely be impacted by the future dam. Endpoints of the modelling included both purely ecological endpoints (e.g. maintaining fish diversity) as well as livelihood associated ecosystem services (e.g. fish for human consumption). A detailed environmental flow requirements analysis designed the flows that would best mitigate these impacts to these services as a result of dam development. Scenarios were developed that linked dam and project design to downstream water flows issues and ecosystem services, and were based on how much water would be abstracted from the system for inter-basin transfer to South Africa (Dickens *et al.*, 2014). The scenarios that were evaluated ranged from including the operation of the dam with full mitigation through releasing the required environmental flows to sustain the ecosystem in the present condition, to extreme scenarios where little water was allowed to pass the dam with the exception of major floods. Thresholds were defined according to a range of development scenarios. Thus for an "environment friendly" dam scenario the targets would be more stringent than for a "maximise water abstraction" scenario where the targets would be lower. The decision on which scenario to accept was and continues to be a socio-political one.

Trade-offs between biodiversity, ecosystem services and human well-being were also considered. Trade-offs were valued to allow for decisions to be made on different scenarios of dam development. The indigenous use of these ecosystem services and the impacts on them by the dam were further valued in monetary terms following stakeholder surveys where the customary practise of their use was established. This allowed decision makers to select a dam development scenario with full knowledge of the trade-offs that would have to be managed, including even some by monetary compensation for loss of ecosystem services.



5.8.3. Tele-coupling

Tele-coupling refers to socioeconomic and environmental interactions over distances. It involves distant exchanges of information, energy and matter (e.g., people, goods, products, capital) at multiple spatial, temporal and organisational scales. Tele-coupling can lead to unexpected impacts that stem from faraway drivers that were not anticipated to have an effect in a particular region.

In the *Market Forces* archetype, multinational corporations take advantage of Africa's open door policy by enabling the flow of resources to overseas markets. These tele-coupled systems typically promote extraction from Africa for the benefit of overseas markets and investors. If places and countries with a lack of regulation or law enforcement (where illegal harvesting and poaching occur) this further exacerbates the outflow of resources and can erode local level food security and development. The *Policy Reform* archetype similarly has an export-orientated development focus that is likely to result in the establishment of tele-couplings with overseas markets in favour of developing regional relationships. This focus is likely to favour the extraction of resources from Africa to the benefit of overseas markets and investors, and may ultimately undermine local level food security and ecosystem service provision. Land grabbing by foreign nations may occur under both these archetypes.

The *Regional Sustainability* archetype is orientated towards the policy-facilitated movement of products and resources across borders and regions within Africa and increases regional connectivity. Whilst there are economic benefits, this archetype may result in regional ecological integrity being traded-off through species invasion, landscape degradation and increased pollution. Furthermore, if regional food production and trade patterns become entrenched, people or nations within Africa who no longer grow their own food will become more exposed to food shortages, particularly given anticipated climate change effects. Due to their localised nature, the *Fortress World*, and *Local Sustainability* archetypes are characterised by much weaker global and regional socioeconomic tele-couplings.

5.9. Conclusion

This chapter provides an assessment of how interactions between nature and society could shape different possible future trajectories of change across Africa in the coming decades. The assessment was achieved through a systematic review of published literature that reports on the future of biodiversity and NCP across Africa (section 5.2), and addresses the possible future trajectories of key drivers of change (section 5.4), the consequences for biodiversity and NCP (section 5.5), as well as implications for human well-being (section 5.6) and policy options (section 5.7). The assessment is structured around a set of archetypes (outlined in section 5.3) that provide a summary of five major alternative futures for the African continent, based on how multiple, interconnected drivers are likely to co-evolve over the coming decades. These different sets of drivers are likely to trigger varying impacts on biodiversity, NCP and human well-being, and different policy measures will be possible and necessary to respond to the challenges raised under each scenario (summarised in Table 5.6). The assessment specifically highlights which priority issues in Africa are likely to be addressed under each of the scenario archetypes, in terms of three key sets of sustainability and development targets: the 2020 Aichi Biodiversity Targets, 2030 SDGs, and the AU Agenda 2063 (Table 5.7).

The scenarios presented in this chapter do not aim to identify or endorse a specific desired future, but rather to provide guidance about what plausible futures may unfold in Africa, including their associated trade-offs, potential tipping points and tele-couplings with the rest of the world (section 5.8). Given the complexity and multiple dimensions of nature's interactions with society, this chapter highlights the need to co-design and co-develop best practices that respond to policy needs, while ensuring that these are appropriate to different social contexts. The scenario archetypes are not predictions of the future, but aim to illustrate a range of possible futures for the continent, and the complex interactions between current environmental and developmental conditions, existing driving forces, and potential policy interventions. Considering how uncertain the future is, the actual future that unfolds in Africa is likely to contain elements of multiple archetypes, as well as some completely new and unexpected features. However, considering a desired future for Africa through the lens of scenarios can enable decision-makers to formulate better decisions about what policy instruments to employ in order to work towards a more desired future, and to understand the potential long-term trade-offs that different choices entail.

Overall, our assessment highlights that Africa is likely to become increasingly interconnected with the rest of the world through global markets and trade. Major drivers related to population, urbanisation, consumption and natural resource use are expected increase under most scenarios, leading to reduced species richness, aquatic functioning, NCP, and increasing trade-offs, especially in the water-food-energy nexus. Despite these challenges, overall improvements in human well-being are expected under most scenarios, but these improvements typically come at the expense of the environment (Table 5.6). Consequently, various targets aimed at facilitating transformative changes that achieve both human well-being and environmental sustainability outcomes have been adopted in Africa and globally (2020 Aichi Biodiversity Targets, 2030 SDGs and AU Agenda 2063).

This chapter highlights clear gaps in the type and distribution of African scenario studies, with some subregions (central, north and west Africa), issues (non-climate-related) and perspectives (ILK), being particularly poorly covered. There is a major need for building the capacity of African researchers, policymakers and institutions to understand, carry out and use scenario analyses. In particular, there is a need to broaden the focus of African scenario studies beyond modelling climate change impacts, and especially to better incorporate broad stakeholder participation and ILK into scenario processes. The potential for using scenarios to support decision-making in Africa, particularly around potential risks, opportunities and trade-offs of the different future pathways of change, will only be realised if concerted efforts are taken to mobilise financial and other resources to build capacity for carrying out and using scenario analyses.

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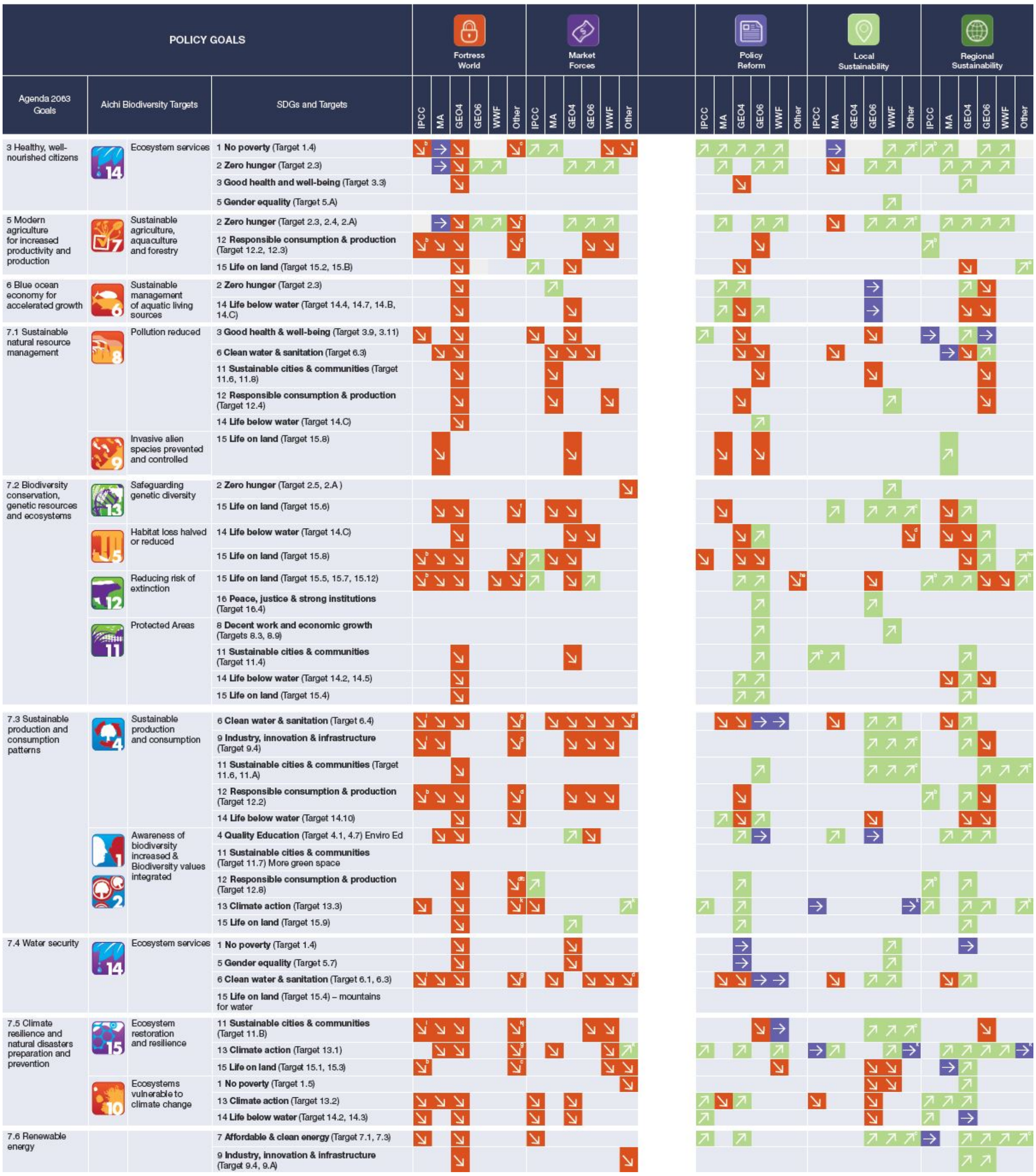
Appendix 5.1: Detailed analysis of the likelihood for achieving different policy targets under the five archetypes assessed in this chapter.

Arrows indicate an increase (↗), decrease (↘), or no change (→) in biodiversity and ecosystem function under each scenario type. The colour of the cell indicates the overall trend across the reports, where green indicates overall increase, orange indicates overall decrease, purple indicates contradictory trends, and no colour indicates no overall change or unknown effects. Some arrows are annotated to indicate the source of the finding (beyond the core reports) as follows: a) Thornton *et al.* (2009); b) Nakicenovic *et al.* (2000); c) Lambin *et al.* (2014); d) Bohensky *et al.* (2006); e) Alcamo *et al.* (2005); f) Visconti *et al.* (2016); g) WWF-AfDB (2015); h) Biggs *et al.* (2008); i) Niang *et al.* (2014); j) Maina *et al.* (2013); k) O'Neill *et al.* (2017).



Chapter 6: Options for governance and decision-making across scales and sectors

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Executive summary

African populations share a close relationship with, and are highly dependent on, biodiversity and ecosystem services. A major challenge lies in managing and governing this human-environment relationship for Africa's transformation towards sustainability and resilience *(high agreement, robust evidence).* A wide variety of governance options exist in Africa for the conservation of biodiversity and sustainable delivery of ecosystem services and benefits to people under a range of future scenarios. Progress in achieving the Strategic Plan for Biodiversity 2011–2020 and Aichi Biodiversity Targets, the 2030 Sustainable Development Goals and African Union Agenda 2063, will be shaped by the governance choices made on the continent (Chapter 5, Table 5.7). Good environmental governance is critical for enabling Africa's diversity to deliver ecosystem services to people. A polycentric governance system has always been practiced in Africa and has addressed different interests in managing natural resources. It is grounded in the processes of accountability through stakeholder and actor engagement, harnesses co-benefits and value added, and addresses trade-offs. As such, it entails working across scales, sectors, values and knowledge systems including indigenous and local knowledge and institutions and adaptive management. It also involves building a sense of social responsibility and vigorously pursuing 'no regrets' options, particularly in relation to drivers of changes (identified in Chapter 4) {6.1, 6.2.1, 6.4.5}.

African countries are party to a number of global environmental agreements and have made high-level commitments to achieve their targets. The commitments made aim to improve the conservation and sustainable use of biological resources. The implementation of the agreements by African parties needs to be supported by financial, human and infrastructure capacity and accompanied by efforts to mainstream biodiversity, ecosystem services and nature's contributions to people into regional, subregional, national and sectoral development frameworks {6.2.1, 6.3}.

Domestication and effective implementation of commitments on environmental global agreements is important for African countries to attain sustainable development *(high agreement, robust evidence).* Regional integration policies are extremely important considering the shared resources and the transboundary nature of Africa's freshwater and terrestrial ecosystems including transhumant systems. National policies must balance these higher-level needs with policies that support ecosystem service delivery to constituents. Polycentric governance and decision-making at and across multiple policy sectors and levels will be necessary in order to tackle related challenges, and can highlight opportunities for adopting innovative African approaches towards good environmental governance.

Indigenous people and their livelihoods are underrepresented and overlooked in international agreements and commitments *(high agreement, medium evidence).* In the African context, where people are highly dependent on biodiversity and ecosystem services for their everyday well-being, it is critical to incorporate indigenous and local knowledge in policy decisions around the management of nature's contributions to people. Only three of the existing agreements reported in this chapter (Table 6.2) are specific to indigenous people's rights and livelihoods and offer opportunities for only limited positive impacts. Policy processes would benefit from the explicit inclusion of indigenous people's organisations such the Indigenous Peoples of Africa Coordinating Committee to ensure the inclusiveness and relevance of existing and new regulatory instruments.

Weak institutions in many African countries undermine governance of biodiversity and ecosystem services. There is need to prioritise environmental governance across scales in order to

support the equitable use of resources and conservation *(high agreement, medium evidence).* Institutional failures are among the main drivers of biodiversity loss and ecosystem degradation. Proposals to correct institutional failures, including market failures such as environmental externalities, and legal and policy failures such as the absence of secure property rights or distorted subsidies, must be both practicable and lead to better protection of biodiversity while balancing the ecological footprint of Africa's growing population and industrialisation ambitions. Good environmental governance requires integration, coordination, harnessing synergies between formal and indigenous governance, and managing conflicts. It entails coordination in planning and implementation to diminish elements of uncertainty, reduce competition over resources and reinforce coherence and positive impacts, as well as allowing for analysis of cross-sectoral trade-offs in decision-making to achieve ecosystem sustainability.

Governance options that harness synergies and deliver multiple benefits can help to balance patterns of access and allocation of ecosystem services in Africa. Such governance linkages may also contribute towards poverty reduction and support resilience building more widely *(high agreement, robust evidence).*Harnessing synergies in multilateral agreements, protocols, Sustainable Development Goals and related targets and initiatives can foster the effective implementation of policies and strategies at different levels and scales and help to improve efficiency in the use and allocation of limited resources. Using existing entry points in spatial planning and land-use and management to leverage synergies can be particularly effective for policy implementation at regional and national levels. Africa's radical transformation towards sustainability in line with the 2030 Agenda for Sustainable Development and Agenda 2063 will depend on investments targeting multi-stakeholder, multi-level adaptive governance {6.3}.

Different policy instruments and governance options that address specific drivers (identified in Chapter 4), together with scenarios, (identified in Chapter 5) exist. However, challenges and opportunities arise, with choices creating or reinforcing particular patterns of 'winners' (who make gains) and 'losers' (who bear costs) *(medium agreement, medium evidence).* It is necessary to develop a suite of responses and to be aware that there is no single "correct" policy pathway. Rather, it is important to take steps so that policies are synergistic and coherent, and that new policies are able to make up for the weaknesses inherent in existing ones. Challenges to the sustainable provision of biodiversity and ecosystem services such that nature can continue to support Africa's human well-being are significant, requiring specific policy instruments that target conservation of unique and globally important biodiversity, and better articulation of nature's specific benefits to people, as captured in the Sustainable Development Goals. Challenges of population growth, food security, urbanisation, climate change, land degradation, ineffective/poor governance and path-dependent (unsustainable) historical development decisions, mean that achieving governance that works for both nature and society is not straightforward. Articulating clear processes, which allow the environment to contribute to food security through Africa's agricultural biodiversity, supporting ecosystem services (e.g., pollination, pest control, soil carbon), land restoration, and increased resilience to climate change, are critical to inform the decision-making process. Placing justice and fairness concerns at the centre of the continent's governance priorities can help to improve both the environment and human well-being, while also achieving key international biodiversity and development targets *(high agreement, robust evidence)* {6.1, 6.2, 6.4.6}.

Delivering environmental justice and fairness in access to Africa's diverse biodiversity and ecosystem services lies at the core of 'good environmental governance' on the continent *(high agreement, robust evidence).* Creating an enabling environment for the prioritisation and selection of appropriate policy and governance options depends on addressing political, legal, institutional and economic limitations as well as improving capacities and resources. Strategic adaptive management systems, that incorporate different knowledge systems, are critical to ensuring sustainability of the ecological system and human well-being. Avoiding a ‘tragedy of the commons’ requires effective institutional responses that can enable environmental resources to be managed so that they contribute towards human well-being without eroding natural capital {6.5}.

The African context is complex both environmentally and in terms of multiple governance systems, layers of policies, and different socio-economic trajectories that can be adopted. Policy options need to navigate across these levels and layers and adapt to include multiple interests from the international to local level.

6.1. Introduction

African populations share a close relationship with, and depend upon, biodiversity and ecosystem services for all their human needs. Maathai (2010) noted that Africa's resource conflicts are often fuelled by the need to access nature's benefits in order to sustain livelihoods. There is a critical link between the way natural resources are managed, and peace and security (Gleditsch, 1998). A major challenge lies in managing and governing this human-environment relationship for Africa's radical transformation towards sustainability. Enabling environmental justice and fairness in access to Africa's diverse biodiversity and ecosystem services lies at the core of 'good environmental governance' on the continent, in which transparency, accountability, participation, social justice, and sustainable development principles are integrated (Feris, 2010). Avoiding a perceived or actual 'tragedy of the commons' (Hardin, 1968) requires effective governance responses that can enable environmental resources to be managed so that they contribute towards human well-being without eroding natural capital. Useful lessons may be learned by rekindling traditional African natural resource management methods, which by virtue of being flexible and having strict provisions, are considered by some as largely capable of avoiding a 'tragedy of the commons' (Hardin, 1968). In addition to the African Union Agenda 2063 (AU, 2015), the Sustainable Development Goals (UN, 2015) and the Convention on Biological Diversity's Aichi Biodiversity Targets (CBD Secretariat, 2010) offer valuable international opportunities for framing Africa's diverse biodiversity as a key asset that can, and must, be sustainably and equitably accessed and used in order to reduce inequality and poverty. Nevertheless, there are historical and structural challenges in transforming Africa's environmental governance, and a multitude of environmental frameworks and institutions on the continent (see Chapter 1). Critically, progress towards policy goals will be shaped by the governance choices made.

Africa's encounters with a range of civilisations have precipitated into the concept of Africa's Triple Heritage: dependent, culturally mixed, and politically unstable (Mazrui, 2014). The influences and confluences of these civilisations have affected the structures and functioning of the institutions that govern biodiversity and ecosystem services. Institutions simply refer to conventions, norms and rules that help to determine patterns of resource use (Short, 2007), and can be either formal or informal. The current state of biodiversity and ecosystem services on the African continent (Chapter 1) is a consequence of its history and evolution of human and natural processes (Ash *et al.*, 2010). A good understanding of current and future governance and planning for biodiversity and ecosystem services depends on the legacy of past decisions. Experiences of various African countries reveal that effective conservation and protection of ecosystem services in the past has been lacking. This has been partly due to insufficient recognition of belief systems, customs, land tenure systems and rights to use these resources by former colonial administrations, and has perpetuated post-independence (Akuffo, 2011; Vonada *et al.*, 2011; Muhumuza *et al.*, 2013; see Chapter 1).

The colonisation of African countries and shifts towards a globalised economy, alongside post-independence centralisation, brought about unprecedented governance changes. For example, changes in the traditional institutions governing land tenure systems have deprived many African communities of their rights to use, as well as their rights to apply local knowledge and indigenous knowledge systems to the management of biodiversity and ecosystem services (e.g., Dalle *et al.* (2005) and Dixon (2008) on Ethiopia; Cormier-Salem *et al.* (2010) on Senegal and Guinea Bissau). It is important to seek holistic means of integrating local, regional, and international approaches to valuing biodiversity and ecosystem services, in the context of diverse African indigenous and local knowledge systems that are well suited to environmental conservation.

This chapter recognises the importance of taking a polycentric governance approach to assessing options, where multiple autonomous bodies, often across different sectors and operating at multiple levels and over different time frames, interact within a specific policy arena (Biggs *et al*., 2015) and where space for plural perspectives can be created. A polycentric approach is an alternative to top-down approaches that can be insensitive to local constraints and bottom-up approaches that are sometimes inadequate for dealing with issues at higher levels (Termeer *et al.*, 2010). This chapter highlights the need for systems-based environmental governance and assesses governance options for Africa, to maintain and improve the continent's rich biodiversity and ecosystem services. The structure of the chapter is presented below (Figure 6.1).

The chapter begins by setting out the governance context of biodiversity and ecosystem services in Africa, considering both polycentric and adaptive governance. It then presents an assessment of the existing multi-level policy context at continental, subregional and national levels. Options and mechanisms for mainstreaming biodiversity and ecosystem services into national development initiatives, strategic assessments, economic and financial decision-making are set out and some of the key benefits of mainstreaming biodiversity and ecosystem services are provided. Economic and financial instruments; legal, regulatory and rights-based instruments; and social and cultural instruments, that serve policy and decision-making in improving biodiversity and ecosystem services management, are then discussed. Subsequently, the necessary frameworks and inputs such as capacities, tools, methodologies and resources in creating an enabling environment for biodiversity and ecosystem services governance are discussed. Building on the information outlined in SPM Table 2, Tables 5.6 and 5.7, and Appendix 5.1 where policy options in response to scenario archetypes are outlined, the chapter then summarises key policy instruments for achieving biodiversity and ecosystem services specific policy goals.

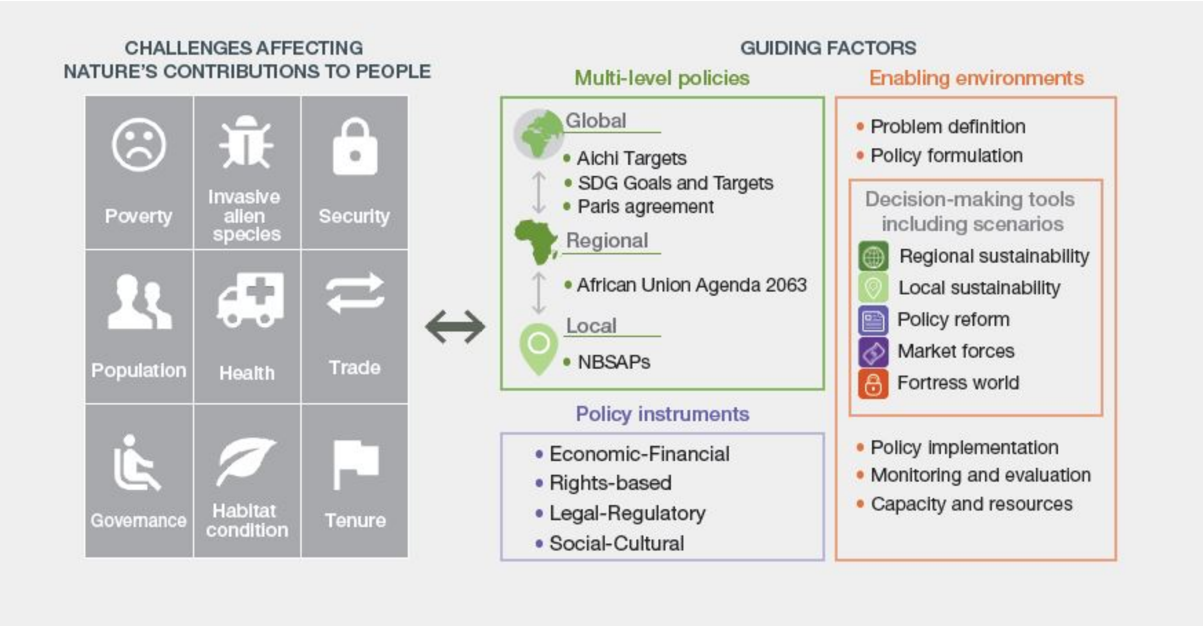

Figure 6.1: The flow and development of chapter 6. The left panel shows the complex situation in Africa as laid out in Chapter 1. The green box represents the policy context within which Africa must work towards achieving various goals at multiple scales. There are a number of policy instruments (in the purple box) that can be used to guide Africa towards these goals, but in order for the policy instruments to work and the goals to be attained there needs to be an enabling environment (orange box). Together, the elements in the boxes can guide Africa towards a desirable future (see Figure 6.7).

6.2. Governance of biodiversity and ecosystem services in Africa

The governance and policy context provides a hierarchical, multi-level framing to address current challenges in maintaining and sustainably using Africa's natural capital over the different time frames of their implementation. At the national level, African countries have developed policies and strategies to respond to and align with global, regional and subregional scale development policies and strategies. However, ecosystems are dynamic, so it is imperative to identify which governance arrangements can be used to deal with future conditions, aspirations and uncertainties, especially as inter-linked systems often have non-linear feedbacks that can lead to irreversible changes in systems or regime shifts (Duit *et al.*, 2008). A key opportunity arises to integrate the concept of adaptive, flexible governance systems that can deal with future uncertainties into more mainstream governance approaches to ecosystem management (Berkes *et al.*, 2003; Chapin *et al.*, 2009; Novellie *et al.*, 2016). Furthermore, there is a need to deal with the transboundary nature of ecosystems and in particular the strong inter-dependencies of the food-energy-water nexus and other complex challenges noted in earlier chapters (see e.g., Chapters 1 and 4).

Adaptive governance has been put forward as a way in which to manage and cope with multiple and cross-scale interactions in social-ecological systems, especially during periods of abrupt change (Folke *et al.*, 2005). Key aspects of adaptive governance include the emergence of 'bridging organisations' that can lower the costs of collaboration and conflict resolution. They can also assist the development of policy and legislation that can support actors within the system to self-organise and therefore react more quickly, effectively and creatively to shocks (Folke *et al.*, 2005; Olsson *et al.*, 2006). Polycentric governance arrangements are important for being able to realise adaptive governance and facilitate collective action in tackling global environmental problems, such as climate change and deforestation, at multiple levels (Ostrom, 2010; Schoon *et al.*, 2015).

The flexible institutional arrangements of polycentric governance systems are often criticised for being inefficient because they are non-hierarchical and complex in their organisation. Yet, in practice, they provide a framework that enables resource users at multiple levels to draw on general principles to craft new institutions that cope with changing situations on the ground (e.g., Folke *et al.*, 2005; Barau *et al.*, 2016; Novellie *et al.*, 2016; Ward *et al.*, 2018a; Figure 6.2). Furthermore, polycentricity provides a governance structure that can enable learning and experimentation, participation, connectivity and diversity, which are important characteristics for building resilient ecosystems (Schoon *et al.*, 2015). In the African context, it is even more important to create these plural governance spaces that acknowledge diverse and multiple knowledge systems and framings of nature (see also section 6.5.3 and Figure 6.5). However, building polycentric governance systems is not a simple task and can be derailed by conflicting interests.

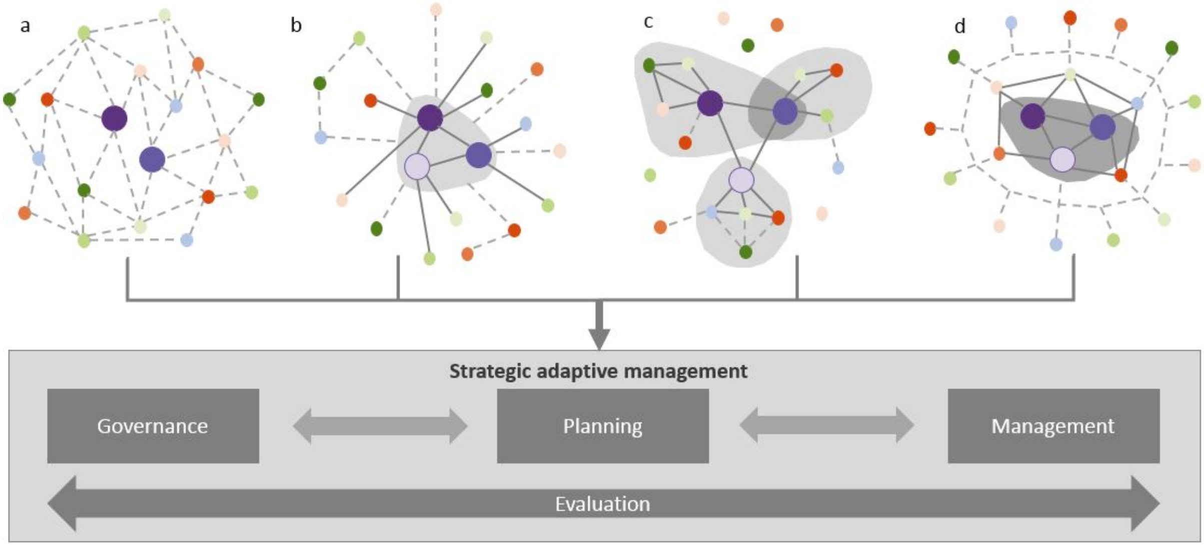

Figure 6.2: Polycentric and adaptive governance from 'weak' to 'strong' polycentricity across the four adaptive processes of strategic adaptive management. The figures a, b, c and d illustrate different processes of polycentric coordination and order: (a) illustrates a simple communication network that allows for mutual adjustment in multi-actor settings; (b) illustrates a stronger form of coordination as it combines communication linkages (dotted lines), with formal partnerships arrangements (solid lines); (c) denotes a stronger form of polycentricity involving tangible joint projects/experiments between actors (shaded areas) often with overlap; and (d) is the strongest form of polycentric order, and involves strong formal ties between key actors as well as a suite of joint projects, and the evolution of rules. Some external communication linkages to peripheral actors (dotted lines) co-exist with this stronger form of polycentric order often denoted as the 'polycentric system'. Colours illustrate the diversity of actors, and sizes are rough illustrations of the importance that different actors (nodes) play in the evolving network. These different configurations are important to understand at different stages of the adaptive management cycle as different configurations may be more appropriate depending on the level of co-production of knowledge it requires. Source: Galaz *et al.* (2012).

As governance becomes more polycentric and networked, the active alignment of political and institutional factors becomes necessary, both across the same level (horizontal integration) and between different institutional levels (vertical integration) (Varis *et al.*, 2014). While institutions and platforms that facilitate cross-sector interaction and learning can assist with this (see Stringer *et al.* (2014) for examples of multi-stakeholder coordination platforms linked to managing climate change in Zimbabwe and Zambia), in the absence of such mechanisms, policy conflicts, competition for scarce resources and duplication of efforts can ensue (Stringer *et al.*, 2009; 2012). Ostrom (2010) highlights that devolving some decision-making to the local level whilst being able to maintain higher-level strategy is an important component for governing natural resources. This is particularly the case in situations with complex mixes of public and private decision-making. Box 6.1 provides an example of the challenges in implementing such a polycentric governance in Guinea (Abe *et al.*, 2016). Other African countries provide further insights. Muller (2012) and Pollard *et al.*, (2011) focus on adaptive water governance in South Africa, while Ethiopia allows its regional states and indigenous institutions to be involved in decision-making (Hailu *et al.*, 2008).

Box 6.1: Polycentric governance in the Gulf of Guinea Large Marine Ecosystem

Out of a region-wide concern to curb continued degradation of the marine ecosystems and the risk of coastal erosion, 16 countries sharing the Gulf of Guinea Large Marine Ecosystem collectively initiated a trans-boundary project with a governance model that targeted actions to improve the socioeconomic conditions of the population across the shared coastal marine ecosystem. The broad objectives of the project were to recover depleted fishery stocks and ensure their sustainable utilisation, to reduce further pollution of the ocean and restore and maintain a healthy ecosystem. The success of the governance structure and institutional arrangement was centred on strength of the collective decision-making body, the steering committee formed by the member countries, with a real decision-making exercise by the countries over the management of their coastal marine ecosystem. The governance model resulted in more transparency and built trust among the participating countries easing access to disputed boundaries, which were access-restricted even for research purposes. The multilevel stakeholders (international, regional, national and sub-national) engagement in the governance structure underpinned the success of the project. One unique feature that built support for the initiative was its 'middle out' approach rather than a typical 'top-down' approach. The 'middle out' approach basically started building a network of large marine ecosystem professionals from the different levels of governance. This network worked together with those access to policy decision-makers, as well as engaging with the grassroots actors who utilise the marine ecosystem resources.

Challenges faced by the project, including interruptions of funding, were successfully managed and the effort eventually culminated in the creation of a commission by a protocol to the Convention for the Cooperation in the Protection and Development of the Marine and Coastal Environment of the West and Central and Southern African Region in 2012. The resulting agreement is called the Abidjan Convention.

6.3. Assessing the existing multi-level policy context for the governance of Africa's biodiversity and ecosystem services

Section 6.3.1 assesses the international agreements that constitute the current global policy framework within which Africa's polycentric governance options can be defined. It then evaluates the continent's progress towards the Convention on Biological Diversity's Aichi Biodiversity Targets, highlighting the links between these and the Sustainable Development Goals. Section 6.3.2 assesses the subregional level policy context and 6.3.3 focuses on the national level.

6.3.1. The international policy context

Maintaining and improving Africa's rich biodiversity and ecological infrastructure is essential to address the cross-cutting challenges identified in previous chapters (e.g., see Chapters 1 and 4), enabling nature's endurance, humans to live well in balance with nature, and the sustainable use of biodiversity and ecosystem services. The IPBES document on policy support tools and methodologies (IPBES, 2016a) identifies several Multilateral Environmental Agreements to which most African countries are signatories and that have relevance to biodiversity and ecosystem services, some of which also link to human development. These are set out in Table 6.1, alongside the other Rio Conventions (United Nations Convention to Combat Desertification, United Nations Framework Convention on Climate Change) in terms of their links to biodiversity and ecosystem services in Africa.

Under the Convention on Biological Diversity, African nations address biodiversity and ecosystem services via the Strategic Plan for Biodiversity 2011–2020 (CBD Secretariat, 2010), through their strategies, plans, programmes and projects, legislation and other measures. The Strategic Plan comprises a shared vision, mission, strategic goals and 20 targets, serving as a flexible framework for establishing national and regional targets and promoting the coherent and effective implementation of the Convention on Biological Diversity objectives. Figure 6.3 summarises Africa's progress in relation to the Aichi Biodiversity Targets (see also Appendix 6.1), and demonstrates particularly that the continent has made important progress in awareness-raising about biodiversity by NGOs. There is also an improved understanding of metrics and tools for biodiversity stocktaking, recognising that as consumption of natural resources increases in Africa, the role of indigenous knowledge, science, and technology have also become more critical.

Table 6.1: Links between key multilateral environmental agreements and related protocols, key agreements on indigenous and local knowledge, and biodiversity and ecosystem services in Africa.

Multilateral Environmental Agreement	Focus and overview	Links to biodiversity and ecosystem services in Africa
CBD - *Convention on Biological Diversity*	The United Nations *Convention on Biological Diversity* (CBD Secretariat, 2010) has three objectives: i) to conserve biological diversity; ii) to use its components in a sustainable way, and; iii) to share fairly and equitably the benefits arising from the use of genetic resources. The Convention also has three protocols; the Cartagena Protocol on Biosafety, the Nagoya Kuala Lumpur Supplementary Protocol on Liability and Redress and the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Use. The Strategic Plan for Biodiversity 2011–2020 is a ten-year framework for action by all countries and stakeholders to save biodiversity and enhance its benefits for people. It is a flexible framework used for	Africa, being immensely rich in biodiversity, supports nearly a quarter of global biodiversity, much of which plays a vital role in promoting ecosystem services (UNEP-WCMC, 2016). Although considerable progress has been made in the conservation of Africa's biodiversity, high population growth rates, rapid urbanisation and agricultural expansion, pose enormous challenges in reconciling environmental and economic issues with human well-being. In view of these challenges, there is a need to look into how national governments and other decision-makers can be involved to enhance and facilitate implementation of the Strategic Plan for Biodiversity 2011-2020 as well as progress towards attainment of Aichi Biodiversity Targets. National Biodiversity Strategies and Action Plans are vital instruments in the implementation of the *Convention on Biological Diversity* at the national level as stipulated in Article 6 of the *Convention on Biological Diversity*. It is commendable that 54 African countries are parties to the *Convention on Biological Diversity*, 39 to the Nagoya Protocol on Access and Benefit Sharing, 49 to the Cartagena Protocol on Biosafety and 18 to the Nagoya Kuala Lumpur Supplementary Protocol on Liability and Redress. Although 51 African countries have developed National Biodiversity Strategies and Action Plans, some of which are under revision, in revised or completed forms, a few countries are still

	developing national targets, based on the Aichi Biodiversity Targets. National targets are developed taking into account countries' priorities and capacities and their contribution to the collective efforts to reach the global Aichi Biodiversity Targets.	at the inception stage, preparing their first drafts (https://www.cbd.int/nbsap/default.shtml). As such, concerted efforts are still needed in order to support plans for biodiversity conservation. These can be achieved through the regular update of the national biodiversity strategies and actions plans, and by facilitating policy coherence and mainstreaming of biodiversity within and across sectors, innovation and piloting of new ideas and encouraging the mobilisation of resources (UNEP-WCMC, 2016).
UNFCCC - *United Nations Framework Convention on Climate Change*	The *United Nations Framework Convention on Climate Change* (UN, 1992) provides an overall framework for intergovernmental efforts to address climate change. Its overall objective is to stabilise greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system. The *United Nations Framework Convention on Climate Change* has 196 parties and is the parent treaty of the 1997 Kyoto Protocol, ratified by 192 of the *United Nations Framework Convention on Climate Change* Parties.	All 54 African countries are parties to the *United Nations Framework Convention on Climate Change*. Projections suggest biodiversity losses will be exacerbated directly due to impacts of climate change on habitats. Africa has been centre stage in many *United Nations Framework Convention on Climate Change* decisions on mitigation, adaptation, climate finance, technology transfer, amongst others. For example, the Reducing Emissions from Deforestation and forest Degradation in developing countries (REDD+) agreed in Cancun in 2010 was based on Africa's diverse and dense forest ecosystems. Rural African communities who rely largely on ecosystems are most likely to lose their livelihoods due to the negative consequences of climate change and extremes. However, local level adaptation options are generally ecosystem-based and could contribute to increased ecosystem resilience, biodiversity conservation, carbon sequestration and ecological integrity (CBD Secretariat, 2009).
UNCCD - *United Nations Convention to Combat Desertification*	The *United Nations Convention to Combat Desertification* (UNCCD Secretariat, 1994) aims to combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification, particularly in Africa, through effective action at all levels, supported by international cooperation and partnership arrangements, in the framework of an integrated approach	The *United Nations Convention to Combat Desertification* appreciates that Africa is especially vulnerable to land degradation and drought and provides a framework for action to prevent and reverse degradation through sustainable land management and restoration of degraded ecosystems and the services they provide. Achieving this objective involves long-term integrated strategies that focus on improved productivity of land, and the rehabilitation, conservation and sustainable management of land and water resources, leading to improved living conditions, in particular at the community level. Africa has its own Annex to the *United Nations Convention to Combat Desertification*, highlighting the particular problems experienced by the continent. All United Nations

	consistent with Agenda 21, with a view to contributing to the achievement of sustainable development in affected countries.	member states in Africa are parties to the *United Nations Convention to Combat Desertification*. Conservation and use of biodiversity for its ecosystems services remains one of the primary means of protecting and restoring land from desertification.
Ramsar Convention	The *Ramsar Convention* of 1971 is the world's oldest Multilateral Environmental Agreement. It provides a framework for national actions and international cooperation in order to conserve and wisely use wetlands and their resources (Ramsar Convention, 1971).	There are currently 386 Ramsar sites in Africa in which sites' locations, uses and potentials are documented. Many of these, such as the Barotse floodplain are driven by flood pulse ecosystem services which provide the primary sources of nutrition, irrigation water, and wildlife habitat in the region. It is nevertheless difficult to say if African governments and conservation agencies have successfully implemented the principles of wise use in wetlands.
CITES - *Convention on the Illegal Trade of Endangered Species*	The aim of the *Convention on the Illegal Trade of Endangered Species* (CITES, 1973) is to ensure that global trading of wild animals and plants does not threaten their very existence. The *Convention on the Illegal Trade of Endangered Species* works by subjecting international trade in specimens of selected species to certain controls. All import, export, re-export and introduction from the range of species covered by the Convention has to be authorised through a licensing system. Each Party to the Convention must designate one or more Management Authorities in charge of administering that licensing system and one or more Scientific Authorities to advise them on the effects of trade on the status of the species.	All African countries, except South Sudan, are signatories to *Convention on the Illegal Trade of Endangered Species*. African wildlife and products are particularly susceptible to illegal trade, and the focus on *Convention on the Illegal Trade of Endangered Species* controls – including elephant ivory and rhinoceros horns. There are 4063 animal and plant species that are listed by *Convention on the Illegal Trade of Endangered Species* for Africa (http://checklist.cites.org/#/en), the third most populous regional list following Asia and Central and South America and the Caribbean. Despite its challenges, *Convention on the Illegal Trade of Endangered Species*-based approaches to biodiversity conservation are well established, receive strong international support, and have a significant impact on the public perception of the country in question.
CMS - *Convention on Conservati*	The *Convention on Conservation of Migratory Species of Wild Animals* (CMS, 1979), or the Bonn	Africa retains some of the largest and best-known land migrations made by mammals. Migrations by birds between Africa and both Asia and Europe are numerous and include amongst others the Black Sea

on of Migratory Species of Wild Animals	Convention aims to conserve terrestrial, marine and avian migratory species throughout their range. Parties to the *Convention on Conservation of Migratory Species of Wild Animals* work together to conserve migratory species and their habitats by providing strict protection for the most endangered migratory species, by concluding regional multilateral agreements for the conservation and management of specific species or categories of species, and by undertaking co-operative research and conservation activities.	Mediterranean flyway, the East Atlantic Flyway and the West Asian - East African flyway. These migrations are critical to biodiversity conservation, and in some cases, such as the Wildebeest migration, generate significant revenue through environmental tourism. Conservation of this biodiversity requires coordination between governments to facilitate movement across borders as well as land-use change policies that limit conflict between open migratory pathways and either agricultural or infrastructure development (including fencing).
ITPGRFA - *International Treaty on Plant Genetic Resources for Food and Agriculture*	The *International Treaty on Plant Genetic Resources for Food and Agriculture* (FAO, 2009) is an international agreement that aims to guarantee food security through the conservation, exchange and sustainable use of the world's plant genetic resources for food and agriculture, as well as fair and equitable benefit sharing arising from its use.	Africa is the centre of origin for more than 20 commonly traded crops (e.g., millet, sorghum, coffee, yams, cotton, okra), and crops with important nutritional, climate adaptation and market potential (e.g., teff, enset, fonio). Countless local species are used in day-to-day culinary traditions and are gaining increasing attention for their contribution to local dietary diversity and nutrition, as well as global interest in novelty crops and superfoods. The drought tolerance traits of sorghum and millet are driving a growing interest in the cultivation of these plants outside Africa in response to climate change or reduced access to groundwater. The treaty ensures that the benefits of trading such crops are received by ‘custodian’ farmers that have cultivated them. Smallholder farmers in Africa are notably dependent on the local trade of seeds and varieties. The Treaty seeks to ensure the continued capacity to trade seeds between individuals.
WHC - *World Heritage Convention*	The *World Heritage Convention* (UNESCO, 1972), also known as The Convention on the Protection of the World’s Cultural and Natural Heritage was adopted by the United Nations Educational, Scientific and Cultural	Africa is home to 135 listed World Cultural and Natural Heritage sites across 37 countries. These sites, however, are in danger or threatened by one or a combination of accelerated deterioration, large-scale public or private projects development, rapid urbanisation and increased tourism, changes in land-use and tenure, armed conflict, fires, earthquakes, landslides, volcanic eruptions, floods, tidal waves and changes in water levels. In view of this, parties

	Organisation in 1972. The instrument aims to inventory, recognise and protect unique and irreplaceable locations of universal value. Through this convention, parties agree to amongst others: adopt a general policy giving cultural and natural heritage a function in the life of the community and to integrate the protection of that heritage into comprehensive planning programs, and set up services for the protection, conservation and interpretation of that heritage.	to the *World Heritage Convention* pledge to conserve the cultural and natural sites within their borders that are recognised by the Convention as being of exceptional and universal value. In return, the international community helps to protect these treasures. In adherence to the treaty, Parties identify and nominate properties in their national territory to be considered for inscription on the World Heritage list. In doing so, they provide details of how the property is protected and a management plan for its upkeep. Parties are also expected to protect the World Heritage values of the properties inscribed and are encouraged to report periodically on their condition. Because it is the responsibility of member countries to safeguard World Heritage properties in their jurisdiction, they work closely with the World Heritage Committee which also compiles the List of World Heritage in danger.
UNDRIP - United Nations Declaration on the Rights of Indigenous People	The *United Nations Declaration on the Rights of Indigenous People* (UN, 2008) is an international instrument to enshrine the rights that "constitute the minimum standards for the survival, dignity and well-being of the indigenous peoples of the world."	Indigenous peoples are unique holders of knowledge on biodiversity and ecosystem services. By codifying the rights of indigenous people worldwide, protection against forced land dispossession, for self-determination, secured land tenure, right for cultural expression, and any form of association with land, nature and biodiversity the *United Nations Declaration on the Rights of Indigenous People* provides improved opportunities for indigenous people to continue to care for and nurture their bio-cultural heritages, thereby contributing to biodiversity conservation (Cittadino, 2014; Wright *et al.*, 2014).
Swakopmund Protocol	As part of the African Regional Intellectual Property Organisation, the *Swakopmund Protocol on the Protection of Traditional Knowledge and Expression of Folklore* (ARIPO *et al.*, 2010) codifies the protection of traditional knowledge held by African indigenous people from commercial exploitation by national and multinational corporations and provides ways of compensating or benefiting indigenous people for the use of their traditional	By protecting the traditional knowledge of indigenous people in Africa, this protocol enables the conservation and protection of biodiversity, sacred places, specific fauna and flora from commercial and other forms of exploitation, thereby contributing to their protection (Hinz, 2012)

	knowledge.	
AUPFP - African Union Policy Framework for Pastoralism	The *African Union Policy Framework for Pastoralism* (AU, 2010) aims to secure, protect and improve the lives, livelihoods and rights of African pastoralists. The policy framework emphasises the need to fully involve pastoralist women and men in the national and regional development processes from which they are supposed to benefit. It emphasises the regional nature of many pastoralist ecosystems in Africa and therefore, the need to support and harmonise policies across the Regional Economic Communities and Member States.	Through a plan or proposition to secure sustainable pastoralism that allows traditional movement of pastoralists across large expanses of drylands, enabling them to follow traditional grazing cycles, the framework promises to encourage pastoralism that avoids the 'tragedy of the commons', where regulated pastoralism enables the utilisation of rangelands, without causing land degradation and biodiversity loss. The policy framework has the following two objectives: (1) Secure and protect the lives, livelihoods and rights of pastoral peoples and ensure continent-wide commitment to the political, social and economic development of pastoral communities and pastoral areas; and (2) reinforce the contribution of pastoral livestock to national, regional and continent-wide economies.

The SDGs (2015–2030) provide a further important international framing to the continent’s environmental governance. They stipulate various measures and actions to be taken by national governments, directly targeted towards the protection, restoration, conservation and sustainable utilisation of ecosystems and biodiversity resources. They also support responsible consumption and production. Key to biodiversity and ecosystem services approaches in Africa is demonstrating how investments in SDG 15 (focused on protection, restoration and promotion of sustainable utilisation of terrestrial ecosystems, sustainable management of forests, combating desertification, and reversing land degradation and biodiversity loss) significantly contribute to human well-being (e.g., SDGs 1, 2, 3, 6, and 7, on poverty reduction, food security, health, watershed management, energy production and ensuring economic growth without harming the environment). In addition, SDGs 11, 13 and 14 focus on building resilience to climate change impacts by strengthening adaptive capacity, policy responses and through conservation and sustainable utilisation of coastal and marine ecosystem resources.

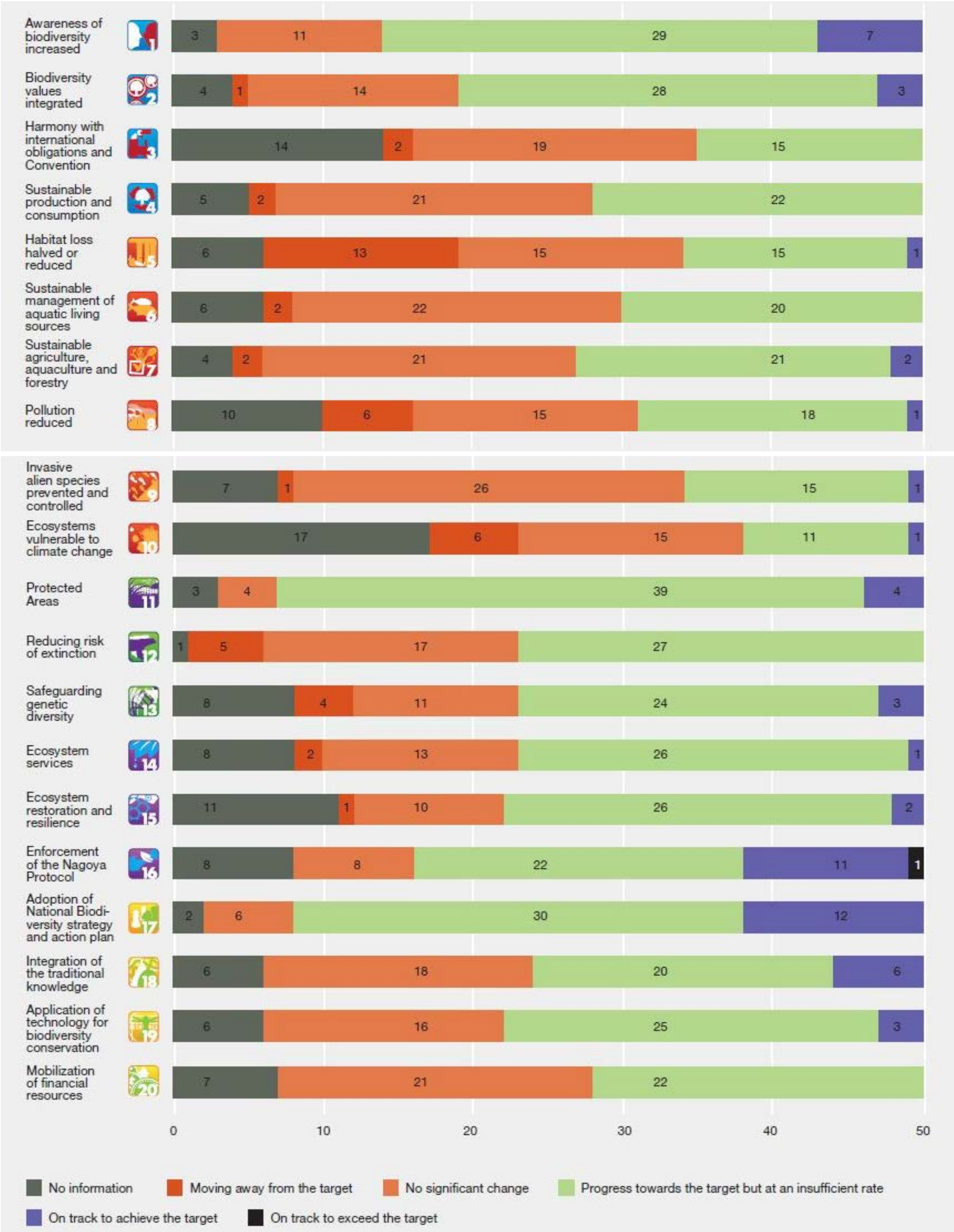

Figure 6.3: Overview of the current and anticipated contribution of African countries towards the achievement of the Aichi Biodiversity Targets based on the fifth national reports submitted to the secretariat of the Convention on Biological Diversity as of September 2017 (50 African States). The figure paints a mixed picture with progress towards some targets substantially outperforming that of others. For example, there are worrying trends where more than 50% of countries are not on course to meet Targets (e.g., Targets 3, 4, 6, 12 and 20 show no countries on track). Of particular concern is target 5, where more than 25% of countries are moving away from the target, while targets 2, 3, 4, 5, 6, 7, 8,

9, 10, 12, 13, 14, and 15 show no significant change for more than 25% of countries. Overall, progress is being made, but at an insufficient rate by more than 50% of countries towards Targets 1, 2, 11, 12, 14, 15, 17 and 19. Target 16, however, has one country set to exceed the target. All targets face a lack of information on progress from some countries. Source: adapted from UNEP-WCMC (2016).

Overall, there is a complex international policy landscape in which Africa's polycentric environmental governance options are situated. Despite the multi-scale, polycentric complexity, decision-making about biodiversity and ecosystem services at smaller scales plays a central role in making progress towards these global targets. Using existing entry points within these international agreements to leverage synergy can be particularly effective for policy implementation at regional and subregional levels, ensuring a resource efficient approach (Akhtar-Schuster *et al.*, 2011). However, globally there is a still a weakness in policy implementation and enforcement, complicated by issues such as corruption.

6.3.2. Africa's regional and subregional policy context

The main policy at the continental scale is Agenda 2063, which sets out an African approach. Through this, Africa can effectively learn from the past, build on current progress and harness opportunities in the short and medium terms to ensure positive socio-economic transformation in the next 50 years. The continental governance structure, supported by other policies and initiatives, offers opportunities to ensure that there is more effective balance in the use and conservation of biodiversity and ecosystem services in the region. This is important because many African countries share cross-border systems such as lakes, rivers and wetlands (e.g., the Okavango Basin/delta, Lake Chad Basin, Victoria Basin/lake, Nile Basin/delta and Niger Basin/delta, Congo Basin, Volta Basin), as well as national parks and sanctuaries that are rich and diverse in flora and fauna. Appendix 6.2 summarises some of the transboundary natural resources and their corresponding governance agreements.

Managing these natural resources requires coordinated cross-border governance structures as well as regional and subregional cooperation agreements. Box 6.2 provides examples of these relating to transboundary water and land resources governance; Box 6.3 presents examples of fisheries regulatory instruments, and; Box 6.4 considers the conservation of genetic resources at a regional level. Most of the institutions and policies are linked to regional economic groupings, for example, the Southern African Development Community's Regional Biodiversity Strategy (SADC, 2008), and the Regional Strategic Action Plan for Integrated Water Resources Development and Management (SADC, 2016), while Central Africa's Forest Commission (COMIFAC, 2014) coordinates the implementation of decisions of the Council of Ministers of its member states regarding conservation and sustainable management of forest ecosystems in the Central Africa region.

Box 6.2: Examples of transboundary water and land resource governance in Africa

The Lake Tanganyika Basin, Lake Victoria Basin and Upper Nile Basin all have trans-boundary agreements/conventions and governing authorities. The Convention on the Sustainable Management of Lake Tanganyika sets out the rights and duties of Burundi, Democratic Republic of Congo, Tanzania, and Zambia, establishing institutional structures for co-operative management. The Nile Basin Initiative aims to achieve sustainable socio-economic development through equitable utilisation of, and benefit from, common Nile Basin water resources, including the Upper and Blue Nile rivers and their catchments. The East African Community Lake Victoria Basin Commission was established in 2001 to promote, facilitate and coordinate activities of different actors towards sustainable development and poverty eradication of the Lake Victoria Basin (International Waters Governance, n.d.). The Volta Basin Authority, representing the six riparian countries in the Volta watersheds, has established an ambitious Strategic Action Plan for which half the budget and activities target restoration of ecosystem functions and conservation (UNEP-GEF Volta project, 2013).

A notable example from West Africa is the New Partnership for Africa's Development and its Great Green Wall of the Sahara and Sahel initiative supported by the Global Environment Facility (GEF *et al.*, 2011). The Great Green Wall of the Sahara and Sahel involves reforesting a 15 km strip of land stretching 7,100 km from Dakar, Senegal to Djibouti and the use of sustainable land management practices to enhance productivity (http://www.greatgreenwallinitiative.org). Specific ecosystem services targeted include carbon sequestration (climate change mitigation), nitrogen fixation, soil retention, regulation of climate extremes (floods and droughts) and provision of habitat for biodiversity (Abdou, 2014). Endorsed in 2007 by African Heads of State and Government, the Great Green Wall for the Sahara and the Sahel Initiative aims to reverse land degradation and desertification in the Sahel and Sahara, whilst mitigating social, economic and environmental crises for the region's most vulnerable people (Hertsgaard, 2011). The Initiative has since evolved into a regional vision of sustainable landscapes that generate multiple economic and environmental benefits and help build the resilience of the Sahel, where over half the population lives on less than $1.25 per day, and nearly 70% depend on the services provided by land resources. A new push for Africa's Great Green Wall Initiative also involved the establishment of a regional hub for the World Bank Sahel and West Africa program to share knowledge and strengthen institutional capacity. Through Global Environment Facility funded initiative, the project dubbed 'Building Resilience through Innovation, Communication and Knowledge Services', provides operational, technical and knowledge services to partner countries under World Bank Sahel and West Africa program. The 'Building Resilience through Innovation, Communication and Knowledge Services' project is a strategic effort designed to boost resilience in the Sahel and help countries and communities adapt to the challenges posed by a changing climate and rapidly degrading natural resource base. The overall aim is to enhance the resilience of landscapes and livelihoods and in doing so, contribute to poverty reduction, food and water security and curb natural resource degradation (O'Connor *et al.*, 2014).

At local level, regional institutions have formulated key recommendations for participating countries, including capitalisation and sharing of experiences acquired in the establishment of the green belts; consideration of existing initiatives and the development of synergies, complementarities and sound coordination with on-going projects and programmes to avoid duplication and improve interventions effectiveness; application of integrated and comprehensive approaches of planning which clarify and strengthen links between the different dimensions of the environment and areas of intervention; and the need to involve local communities, as indigenous and local communities remain fundamental in the successful implementation of the Great Green Wall for the Sahara and the Sahel Initiative. Scientific evidence assessing the effectiveness of the strategy at meeting both conservation and development goals is nevertheless lacking.

Box 6.3: Examples of fisheries and fishery regulatory instruments

The Common Market for Eastern and Southern Africa's Fisheries and Aquaculture Strategy aims to achieve long-term productivity of fisheries and aquaculture, to strengthen food security and the trade benefits of fish products to domestic, regional and international markets, as well as ensuring alignment of programmes and projects in the sector. Similarly, the South West Indian Ocean Fisheries Commission promotes sustainable use of the living marine resources of the South West Indian Ocean region (www.fao.org/fishery/rfb/swiofc/en), while the Indian Ocean Tuna Commission, headquartered in Victoria, Seychelles, promotes cooperation among Members to ensure conservation and optimum utilisation of stocks of tuna and tuna-like species, encouraging sustainable development of fisheries based on such stocks in the Indian Ocean and adjacent seas (www.iotc.org).

Box 6.4: The Southern African Development Community's Plant Genetic Resource Centre

The Southern African Development Community's Plant Genetic Resource Centre is a regional gene bank that works with plant genetics centres in each Southern African Development Community member state to conserve and preserve genetic diversity and viability of southern African plant stocks. The centre now holds more than 18,000 diverse crop and wild relative accessions and is increasing its collection of traditional crop varieties and wild species. Other gene banks in Africa are located in Tanzania, Egypt and Sudan. Ensuring genetic retention of species and variability provides a buffer to local agriculture against shocks such as drought, flood, climate change or civil unrest. Regional fisheries bodies and agreements are also important for the region's management of biodiversity and ecosystem services (www.spgrc.org.zm/).

6.3.3. National level strategies and action plans

The United Nations General Assembly has stressed the need for enhanced cooperation among the Rio Conventions in implementation at national and sub-national levels. This is reiterated in the Sustainable Development Goals, encouraging coordination and cooperation between multilateral environmental agreements. Through the preparation of National Biodiversity Strategies and Action Plans, national and sectoral policies have responded to international agreements such as the Convention on Biological Diversity, alongside the United Nations Convention to Combat Desertification's National Action Programmes and the United Nations Framework Convention on Climate Change's National Adaptation Plans, and Intended Nationally Determined Contributions. Together, these agreements can help to align policies to achieve desired outcomes for biodiversity, climate change and desertification within the broader context of sustainable development. For example, ecosystem-based adaptation can help to achieve the goals of multiple multilateral environmental agreements through national level implementation (Box 6.5).

Box 6.5: Ecosystem-based adaptation to climate change

A very important link between climate change and biodiversity is ecosystem-based adaptation, which provides for conservation, restoration and sustainable use of biodiversity while supporting societies adapt to climate change impacts (Scarano, 2017). Ecosystem-based adaptation is defined as *"the plans/measures that aim at integrating the use of biodiversity and ecosystem services into an overall adaptation strategy. It can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity"* (Doswald, 2014).

Ecosystem-based adaptation measures implemented in many African countries include awareness creation and capacity building for sustainable management of natural resources, use of information and knowledge from all sources, including traditional knowledge, innovations and practices, design of policy measures to protect and control over-extraction of timber trees; establishment of protected areas, watershed management, shelterbelts and agroforestry. These measures have demonstrated multiple economic, environmental, social and cultural benefits by ensuring livelihood sustenance and food security, conservation of biodiversity, sustainable water management, and disaster risk reduction, among other benefits (http://unfccc.int/4159.php).

National Biodiversity Strategies and Action Plans act as national instruments to incorporate biodiversity strategy into development planning. As stipulated in Aichi biodiversity target 17, each party to the Convention on Biological Diversity is expected to have developed, adopted or started implementation of National Biodiversity Strategies and Action Plans by 2015. Fifty-one African countries have National Biodiversity Strategies and Action Plans, some of which are under revision, in revised or completed forms. Some countries (e.g., Libyan Arab Jamahiriya, Somalia and South Sudan) have their first National Biodiversity Strategies and Action Plans under development at the time of writing this assessment. As of 2015, 49 African countries had reported their revised National Biodiversity Strategies and Action Plans to the Convention on Biological Diversity (with national targets for the period 2010–2020). National targets (e.g., reduction of habitat loss by 10%, increase conservation of threatened or endangered species by 30%, reduce impacts of mining on biodiversity, etc.) are well aligned to meeting many of the Aichi Biodiversity Targets by 2020. Nevertheless, moving towards effective national-scale implementation of global multilateral agreements is highly challenging.

According to UNEP (2015), improved coordination between national institutions responsible for various multilateral environmental agreements and relevant ministerial departments and agencies, is critical to the implementation of biodiversity and ecosystem services management strategies in a synergistic way within a polycentric governance system. Synergy can be harnessed between multilateral environmental agreements through mainstreaming national strategies into national and regional development plans, and projects for sustainable development. In turn, mainstreaming can help to identify and mitigate trade-offs. It requires coordinated efforts from many stakeholders (public and private), including intergovernmental and governmental institutions, NGOs, the private sector and local communities, in order to identify solutions to interlinked problems. Such an approach can also help to integrate decision-making across scales from the local to the international.

6.4. Mainstreaming biodiversity and ecosystem services

The post-2015 agenda provides an opportunity to guide development pathways to benefit both biodiversity and poverty alleviation for the many smallholders in Africa, who depend on ecosystems for income, jobs, and food. It focuses particular attention on the status of the numerous female smallholders who face severely restricted opportunity space. Lack of consideration of biodiversity and ecosystem services when making major economic decisions produces a risk associated with crossing tipping points that arise from continued loss of biodiversity. One example of a possible tipping point in Africa is the Sahel, where pressure from climate change, land degradation and over-use of limited water resources threatens to degrade the area, which will further exacerbate desertification (Lambin *et al.*, 2014). This degradation and loss of vegetative cover is likely to have severe impacts resulting in the loss of biodiversity providing soil carbon, and loss of hydrological ecosystem services which are the foundations of food, fibre and water production in Sahelian Africa (CBD Secretariat, 2010; Lambin *et al.*, 2014).

This section examines options for mainstreaming biodiversity and ecosystem services. Some countries have embedded biodiversity considerations into policies, strategies and practices of key public and private actors that impact or rely on biodiversity, so that it is conserved, and sustainably used, locally, regionally and globally (Huntley *et al.*, 2014; Redford *et al.*, 2015).

6.4.1. National development processes

Integrating biodiversity and ecosystem services into development planning can be achieved in a variety of ways. However, there is still a challenge for African countries to coordinate and integrate development objectives with biodiversity conservation. Examples such as the Poverty and Conservation Learning Group (involving International Institute for Environment and Development) and Poverty Environment Initiative (Box 6.6) have nevertheless paved a way for countries like Malawi, Mozambique and Mauritania to mainstream poverty-environment linkages into national development plans (UNDP-UNEP, 2013).

Box 6.6: Malawi Poverty Environment Initiative. Source: UNDP-UNEP (2013).

Prompted by a natural resources economic analysis and evidence of poverty-environment linkages, the government of Malawi has shifted the course of its national development planning. In January 2011 a study initiated by the Poverty-Environment Initiative, a joint programme of the United Nations Development Programme and United Nations Environment Programme, established for the first time the costs and benefits of sustainable and unsustainable natural resource management in Malawi. This quantification was done in four areas of forestry, fisheries, wildlife and soils. The findings showed that unsustainable natural resource use is costing the country the equivalent of 5.3% of GDP each year, more than the total funding allocated to education and health ministries in the national budget. Soil erosion alone reduces agricultural productivity by 6%, and if this yield was recovered, an additional 1.88 million people would have been lifted out of poverty by 2015. The study also revealed the untapped potential of the country's wealth of natural resources for tackling extreme poverty.

The study marked a turning point for both the government and its development partners. The economic analysis not only demonstrated the macro-economic contribution of natural resources to GDP but showed the links between investing in ecosystems and poverty alleviation and has marked a shift in the way government institutions understand the issues. The Poverty-Environment Initiative revealed that the most effective way to mainstream ecosystem management and poverty alleviation into government processes is to get the issues into the core of planning agendas and processes. As a result of the study, Malawi's Growth and Development Strategy II for 2011–2016 identified climate change and natural resource management as one of nine priority areas for the country. This shift in direction at the national level also prompted change across the sectors. As long as the momentum for change is not lost, most policies and plans in Malawi will take into account the linkages that exist between poverty alleviation and natural resources management.

Other countries such as Mali, Botswana and Tanzania have even gone further to include biodiversity and ecosystem services into their Poverty Reduction Strategies. Figure 6.4 shows the degree to which biodiversity is reflected in the Poverty Reduction Strategy Papers of different African countries (UNEP-WCMC, 2016).

In many countries, the most important national sectors have legislation, action plans and programmes which are developed with a wide range of stakeholders (GEF *et al.*, 2007). Mainstreaming biodiversity and ecosystem services into sectoral legislation and plans not only benefits biodiversity but also benefits other sectors because they reinforce the sustainability impacts of legislated activities. Countries like Guinea-Bissau, Malawi, Seychelles, Cameroon (see Box 6.7) and Sierra Leone have incorporated biodiversity conservation into development plans in agriculture and forestry (UNEP-WCMC, 2016).

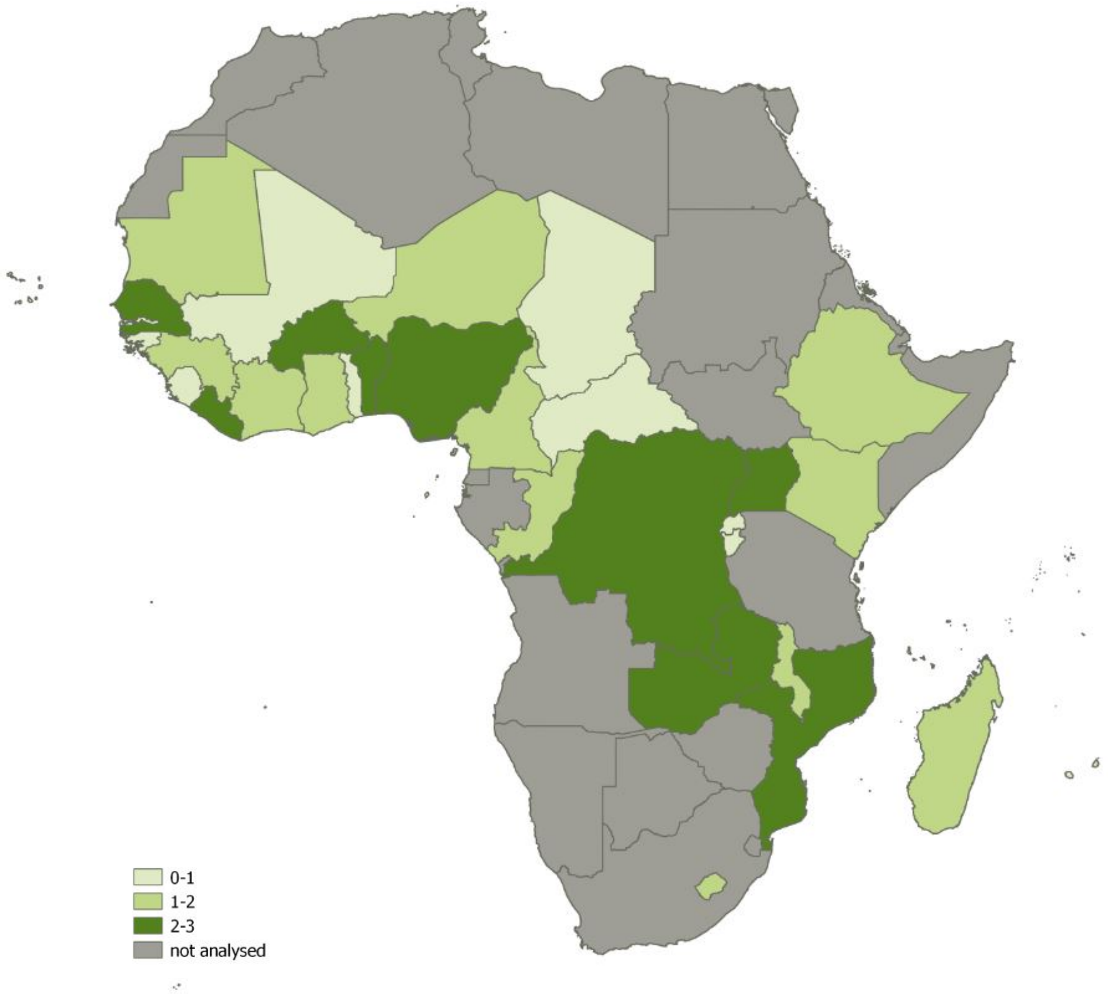

Figure 6.4 Integration of biodiversity and ecosystem services into Poverty Reduction Strategy Papers in Africa, scored from 0-3, using a scale where 0 means that biodiversity is not reflected and 3 means its importance is strongly reflected. Source: UNEP-WCMC (2016).

Box 6.7: Mainstreaming biodiversity in Cameroon. Source: UNEP-WCMC (2016).

Cameroon's national Strategy Document on Growth and Employment is the country's framework for economic development. The Government of Cameroon included its Forest and Environment Sector Programme in the Strategy Document on Growth and Employment, to mainstream biodiversity into its economic development. The main components of the Forest and Environment Sector Programme are: i) knowledge of research and ecological monitoring; ii) development of production forest from state domains and products; iii) preservation of biodiversity and increasing the value of wildlife products; iv) community management of forestry and wildlife resources; v) environmental management of development operations; and vi) institutional strengthening, training and research. Subsequently, the Ministry of Forestry, the main body in charge of the Forest and Environment Sector Programme, assigned the task of implementing key components of the Forest and Environment Sector Programme to the Ministry of Social Affairs, the body responsible for improving the living standard of indigenous people (Eyebe *et al.*, 2012). Through the collaboration between the Ministry of Forestry and the Ministry of Social Affairs, and by incorporating the Forest and Environment Sector Programme into the Strategy Document on Growth and Employment, Cameroon has demonstrated that biodiversity can be mainstreamed into development sectors.

6.4.2. Strategic Environmental Assessments and Environmental Impact Assessment

At regional and national levels, using Strategic Environmental Assessments for the purpose of including ecosystem services in planning provides an opportunity to mainstream ecosystem services into decisions at the strategic level (Ganeletti, 2011; see Box 6.8). A number of countries including Ethiopia, Kenya and Mauritius, have incorporated Strategic Environmental Assessments in their legal frameworks (UNEP-WCMC, 2016), though in several nations it is less explicit.

Box 6.8: Spatial biodiversity planning in South Africa. Source: Driver *et al.* (2012).

South Africa's National Spatial Biodiversity Assessment identifies priority biodiversity conservation areas to guide subsequent land-use policy and decision-making at national, provincial, and municipal levels. Action Plans have been developed for certain priority areas such as the Cape region. The new Grasslands Project aims to promote land-use opportunities compatible with the maintenance of biodiversity and to protect the most vulnerable high biodiversity sites. The National Spatial Biodiversity Assessment targets are aimed at 1) reducing loss and degradation of natural habitat in priority areas; 2) protecting critical ecosystems; and 3) restoring and enhancing ecological infrastructure.

Environmental Impact Assessment offers another approach and has been widely used in Africa since 1995 when African Ministers of Environment endorsed its use at the African Ministerial Conference on the Environment. Numerous Environmental Impact Assessments have been conducted for different development projects and at least 48 African countries have enacted environmental laws, most including specific requirements for Environmental Impact Assessments (UNEP-WCMC, 2016). Environmental Impact Assessments thus provide a promising opportunity for mainstreaming biodiversity and ecosystem services with an emphasis on preventing biodiversity and ecosystem service losses and enhancing nature's contributions to people. However, while there are doubts about the ability of activity or site-specific Environmental Impact Assessments to fully report on the implications of project proposals on biodiversity and the ecosystem services that biodiversity provides and underpins, it nevertheless provides a useful entry point for their consideration within projects (de Villiers *et al.*, 2008).

6.4.3. Benefits of mainstreaming biodiversity and ecosystem services

Considering that the activities of several sectors across scales have an impact on biodiversity and ecosystem services, the wider benefits of mainstreaming biodiversity into plans, policies and financial activities cannot be overemphasised. Without mainstreaming biodiversity into the various sectors, the best efforts at sustaining production sectors' activities are likely to be threatened. An example of benefits from mainstreaming can be found in a study from Uganda, which showed that ecosystem services provided by the Nakivubo Swamp to the Greater City of Kampala, were estimated to have a value of $2 million a year in terms of water purification benefits- equal to the cost of building the infrastructure required to provide a similar service. In comparison, the cost estimation of managing the wetland to enhance its capacity to provide waste treatment services was $235,000 per year. These benefits identified through the study resulted in the reversal of the decision of the Ugandan Government to drain and reclaim the wetlands (UNEP-WCMC, 2016).

It is important that information generated from the assessment of natural capital accounts is used to inform policy decisions to support the mainstreaming of biodiversity and ecosystem services across sectors. Impacts can be further enhanced by disseminating results from these natural capital account assessments with various stakeholders (WAVES, 2013; Box 6.9; Chapter 2).

Box 6.9: Implementing the System of Environmental-Economic Accounting in Africa. Source: UNEP-WCMC (2016).

The *Wealth Accounting and Valuation of Ecosystem Services* partnership initiated in 2010 aimed to mainstream natural resources into development planning and national economic accounts. The partnership has supported three African countries, Botswana, Madagascar and Rwanda, in developing accounting methodologies that take into account natural capital. Botswana has detailed water accounts for 2010–11 and 2011–12 that account for the supply and use of water. This can lead to programmes that support the efficient use of scarce natural resources that would contribute to conservation and sustainable use of biodiversity (World Bank, 2013).

It is critical to monitor and evaluate mainstreaming efforts to determine benefits for biodiversity and ecosystem services, poverty alleviation and development outcomes. Monitoring and evaluation are generally difficult and where there are no nationally agreed upon baselines, it is difficult to develop targets and indicators. There is thus a need to develop monitoring and evaluation frameworks including indicators for biodiversity and ecosystem services mainstreaming in Africa. Policy instruments are vital in supporting this and are considered in the next section.

6.5. Policy instruments

There is a range of policy instruments available and under development to help ensure that nature's contributions to people are manifested and have real impact. These are classified as economic and financial instruments, legal regulatory, and rights-based instruments, institutional aspects and socio-cultural perspectives, and multi-stakeholder approaches. The latter are particularly relevant to bottom-up based approaches and fit for polycentric governance processes in the region; these include community-based natural resource management, public-private partnerships, and co-management approaches. Economic and financial instruments emphasise the value of biodiversity and ecosystem services; they facilitate the integration of nature into development planning by articulating benefits in economic terms. Economic valuation is a complementary tool but is not fully capable of capturing the diversity of benefits nature makes to well-being.

6.5.1. Economic and financial instruments

There is continued debate on whether ecosystems should be viewed as economic assets that produce a flow of beneficial goods and services over time (Barbier, 2013). However, the benefits that biodiversity and ecosystem services provide to human populations are sometimes insufficiently taken into account by decision-makers in African development policies, in part because their contribution to national economies and transitions out of poverty are not always well demonstrated. Costs of biodiversity and ecosystem service loss are rarely internalised (Challender *et al.*, 2015). The interaction of market, policy, institutional and livelihood failures promotes under-valuation of biodiversity and environmental assets, causing public and private sectors to fail to appreciate or account for the cost of biodiversity loss and ecosystem degradation (Barbier, 1994; Dixon *et al.*, 1994; Barbier *et al.*, 1997).

Recognition has grown that economic concepts and instruments can substantially improve the status of biodiversity and ecosystems, as well as support social prosperity and a green economy (Albers *et al.*, 1996; IIED, 2003; also see Chapter 2). A clearer understanding of the benefits that ecosystem services provide to populations in the African context can fuel sustainable development and improve social welfare (AfDB-WWF, 2012) especially in sub-Saharan Africa, where many biodiversity hotspots coincide with poor and growing human populations. Economic incentives can significantly promote biodiversity conservation policies (Amin, 2016).

Economic instruments can also be effectively employed to address economic drivers (see Chapter 4, section 4.4.3) of biodiversity loss and ecosystem degradation. Once the specific drivers are known, relevant economic and financial instruments can be selected to help shift people's behaviour towards promoting biodiversity conservation. Emerton (2014) notes that conservation actions involving behaviour change usually need to be economically attractive for those expected to adopt them, either as a standalone activity or related to alternative (unsustainable) options. Incentives can be broadly considered as direct (e.g., rewards for changes in behaviour) and indirect (e.g., creating enabling conditions that lead to behavioural change). It is important that incentives consider the "specific groups, activities and sectors which they aim to work on" and that they are "based on practically implementable actions, and…acceptable and sustainable within the broader social, political and cultural context within which they are being applied" (Emerton, 2000, p. 19). In this regard, South Africa provides a useful example that links eradication of invasive alien species with poverty alleviation and livelihood diversification (Box 6.10, Chapter 1). Alternatively, mechanisms that penalise people for their actions leading to biodiversity loss, such as taxes, charges and fees, or disincentives, can be applied to support sustainable resource extraction or use rates, or to produce revenue in support of ecosystem service conservation (Panayotou, 1994).

Box 6.10: Incentives to tackle invasive species in South Africa

The South African government's Working for Water programme, founded in 1995, employed marginal communities, mostly unskilled women in rural communities, to clear woody invasive alien plants such as Australian acacia species (wattles), *Pinus* spp., *Eucalyptus camaldulensis*, *Hakea* spp., *Prosopis* spp., and water weeds (e.g. *Eichhornia crassipes*), thus protecting biodiversity and ecosystem services while at the same time providing employment and securing water supplies (Richardson *et al.*, 2004). In 2014, the government had a national list of invasive alien species (total 559) in four categories for management under the National Environmental Management Biodiversity Act (Act 10 of 2004) and its Alien and Invasive Species Regulations. Invasive alien species are sometimes considered the single biggest threat to South Africa's biodiversity (Richardson *et al.*, 2004; van Wilgen *et al.*, 2014a; van Wilgen *et al.*, 2014b). This governance option thus tackled an ecosystem dis-service by seeking to improve ecosystem services.

Economic instruments operate in different ways and through different mechanisms to correct the broader distortions and failures in markets, policies, laws, institutions and livelihoods comprising economic causes of biodiversity loss and degradation. The table in Appendix 6.3 provides several examples of economic incentives and financial instruments and their application in Africa, complementing those found in the boxes throughout this section. A key goal is to ensure people take account of the full economic value of biodiversity and the full economic costs associated with its loss. This needs to be considered when they produce, consume and trade biodiversity and ecosystem services. Total economic values need to be reflected in profits, prices and the returns they produce.

Key economic instruments include property rights, markets and charge systems, fiscal instruments, bonds and deposits, and livelihood support. Property rights grant or allocate rights to own, use and manage biodiversity (see Box 6.11), dealing with the fact that market failure is due in part to the absence of well defined, secure and transferable rights over land and biological resources. Common examples of such instruments include allocation of legal rights, tenure, leases and concessions over the ownership, management and use of biological resources or biodiversity.

Box 6.11: Property rights for access to biodiversity in South Africa

The allocation of community property rights in National Parks and Forest Reserves is particularly widespread (through joint- or participatory forest management etc.). For example, in South Africa, the land upon which Richtersveld National Park lies is owned and occupied by local Nama villages. These communities have leased the land to the government while retaining the right to graze an agreed amount of livestock in the park and to engage in the controlled harvest of certain natural resources. Lease payments are deposited into a trust that has been appointed by the community to manage this resource.

Market and charge systems aim to overcome the distortions and weaknesses in prices and markets that send signals to producers and consumers that encourage them to degrade biodiversity because it is cheaper, easier or more profitable to do so in the short-term. They entail trading in biodiversity goods and services and giving them a price that reflects their relative scarcity, costs and benefits. Examples of market instruments include tradable rights, shares and quotas in biological resources and environmental quality (fishing quotas, pollution permits or development rights), hunting permits, and setting new charges or rationalising existing charges (park entry fees, biological resource utilisation licenses, etc.). Box 6.12 provides an example from Mozambique.

Box 6.12: Access to marine resources in Mozambique

In the Bazaruto Archipelago in Mozambique—one of the country's most vulnerable, diverse and valuable marine areas—a number of new markets and enterprises have been promoted among local fishing communities as a way of stimulating sustainable biological resource use, and in order to compensate for the economic losses in land and natural resources incurred by the establishment of a National Park.

Fiscal measures aim at discouraging or encouraging the consumption and production of certain goods and products that have an impact on biodiversity. The measure could be to raise and spend budgetary revenues on increasing or lowering the relative prices of different products. Typical fiscal measures are taxes and subsidies (see Box 6.13), for example, attaching high tax rates on biodiversity-depleting land-uses, equipment, inputs and products, or providing subsidies to biodiversity conserving technologies, land-uses and enterprises.

Box 6.13: Biodiversity management: role of taxation and fiscal policies

In Ethiopia and Eritrea, energy taxes and subsidies are used as incentives to encourage the use of energy-saving technologies to reduce deforestation for firewood and charcoal. These governments have implemented a series of fiscal reforms in the energy sector which aim to make wood fuel and wood-based cooking technologies more expensive to users. The reforms include subsidies for kerosene, promoting energy efficient wood fuel cooking stoves, and the dismantling of duties on imported solar equipment.

Bonds and deposits are product surcharges which shift the responsibility for biodiversity depletion to individual producers and consumers. They are levied on activities that run the risk of harming biodiversity and require the person carrying out these activities to pay a bond or deposit before they start, refundable against the possibility of this damage occurring. By charging in advance for possible biodiversity damage, bonds and deposits provide funds for covering the costs of this damage and ensure that producers or consumers cover the cost themselves. They also present an incentive to avoid negatively affecting biodiversity and can be applied to natural resource-based industries such as forestry, mining, fisheries and other extractive utilisation activities as a tool to discourage negative biodiversity impacts at the same time as promoting efficiency in resource utilisation (Boxes 6.14 and 6.15).

Box 6.14: Case study of forestry taxation in Liberia. Sources: FAO (2004); Schwidrowski *et al.* (2005).

Liberia is well-endowed with valuable forest resources, and the sector has made an important contribution to GDP over the past few decades. Liberia's forest resources are significant, containing a number of valuable species—such as African mahogany—that are in high demand on world markets. Timber activity began in the late 1960s, driven by low stumpage fees and the establishment of basic road infrastructure that opened access to forest areas. During the first half of the 1980s, the timber sector remained stagnant because of the weak global demand in key markets but also because of political instability in Liberia. The sector had recovered somewhat by the late 1980s, but the outbreak of civil strife interrupted the sector's formal activities until peace was restored in 1997. Thereafter, logging activity recovered very rapidly, driven also by the demand for charcoal and firewood, reflecting the breakdown of the country's regular electricity supply. The surge in logging soon raised concerns about its sustainability. Liberia enacted many charges and regulations for the purpose of forest product utilisation. Government has increasingly adopted pre-harvest fees such as concession fees and area fees. Over time, the number of taxes, charges, and fees on forestry activity has proliferated, driven particularly by the introduction of new taxes for specific purposes. Some of these related to severance charges ($1.50/m3), reforestation charges ($5.00/m3) and conservation charges ($4.00/m3). Apart from these charges on timber products, non-timber forest products also attract charges of various levels. Fines occupy a very important position as a source of revenue to the country. Timber companies are also financially committed under concessions to the construction of schools, clinics, or roads. Furthermore, it became common practice for timber companies to undertake certain tasks that were originally the responsibility of the government, such as road construction, and they were granted tax credits for those activities.

Box 6.15: Regulating biodiversity exploitation in Democratic Republic of Congo

In the Democratic Republic of Congo, a form of deposit bond on commercial forestry operations was established in the early 1990s. This arrangement grants an "interim concession license" which requires loggers to complete various forestry planning and management operations, including forest inventory and investigation of efficient harvesting and processing techniques. If the concessionaire does not make the necessary investments within 3 years, the interim license is cancelled and monies are not refunded.

Livelihood measures acknowledge that livelihoods, and in particular their constraints and shortfalls, can sometimes drive people to degrade natural resources in the search for scarce subsistence, income and employment (see also Chapter 4). By strengthening livelihoods, diversifying them and making them more secure, these measures aim to decrease reliance on biodiversity and put people in a position where they will choose, and can afford, to curtail economic activities that degrade the environment.

These include direct incentives that encourage sustainable use and indirect incentives including diversifying income options and reducing reliance on non-renewable extractive activities with strong biodiversity impacts. A good example of such an instrument is community benefit-sharing, which is a widely-used livelihood incentive for biodiversity conservation, using revenues generated by protected areas to finance development activities in adjacent rural areas (Box 6.16).

Box 6.16: Biodiversity benefit-sharing

Forest and wildlife departments in East Africa (e.g., in Ethiopia and Kenya), engage in benefit-sharing activities around protected area buffer zones. Kenya Wildlife Service's revenue sharing policy is typical, using a Wildlife Development Fund as a mechanism to distribute some of the revenues earned from protected areas to local communities (from entrance fees). A significant amount of money was spent on community-related activities in protected area buffers zones, including water, education, health, livestock and enterprise development as well as the provision of famine relief.

Other instruments such as subsidies, tradable permits, eco-labelling, liability and compensation schemes are incentive-based and include pricing mechanisms to stimulate biodiversity conservation and enhance the provision of ecosystem services. They can target both consumption side and production side actors and stakeholders (Box 6.17).

Box 6.17: Sustainable consumption: Managed marine protected area network, Madagascar. Source: Harris (2007).

In order to preserve local ecosystems and maintain traditional livelihoods and fisheries, Village leaders in the community of Andavadoaka partnered with marine conservationists to develop sustainable harvesting of octopus so as to protect local ecosystems and maintain traditional livelihoods. A plan was developed using both modern scientific methods and traditional ecological knowledge. This led to the seasonal bans on octopus harvesting and the establishment of marine protected areas that also include no-take zones. This initiative has resulted in increased number and size of the octopus caught. The project has been scaled-up to include twelve other communities to create a marine protected area network. The community is also engaged in eco-tourism activities for extra income.

Mainstreaming biodiversity into production and consumption practices can be assisted through the participation of relevant stakeholders in the development and review of guidelines for sustainable management (GEF *et al.*, 2007). Such guidelines can include standards, codes and good practices to support sustainable resource management. The African Ministerial Conference on the Environment launched the African 10-Year Framework of Programmes on sustainable consumption and production to assist African countries to achieve sustainable consumption and production. One of the key initiatives launched by the 10-Year Framework of Programmes is the African Eco-labelling Mechanism. In addition, National Cleaner Production Centres have been established in countries such as Cape Verde, Egypt, Kenya, Ethiopia, Ghana and Morocco amongst others. These centres are responsible for capacity building, demonstrating the economic and environmental benefits of sustainable consumption and production and promoting new business opportunities (UNEP-WCMC, 2016). Box 6.18 showcases involvement with the private sector.

Box 6.18: Engagement with private sector in South Africa. Source: IIED *et al.* (2015).

Biodiversity and mining, is important to South Africa's economy, resulting in controversies between mining companies and civil society groups. This led to a joint initiative by the conflicting groups and the government to establish mutually agreed solutions. The South African Mining and Biodiversity Forum brought together industry, civil society, government and academic representatives to discuss the generation of a set of guidelines for the management of biodiversity and mining activities. Consensus-based and voluntary guidelines were preferred to regulation. The guidelines were framed to create an understanding of the ecological needs the mining companies while acknowledging existing business risks and opportunities. The guidelines were launched in May 2013 at an event attended by the Minister of Water and Environmental Affairs, the Minister of Mineral Resources, the Chamber of Mines and the and South African National Biodiversity Institute. This collaboration demonstrated a new attitude among policymakers towards the country's shared natural assets.

Another approach of growing importance is that of geographical indications, which point to the origin of particular products and imply that they contain specific properties or characteristics (Box 6.19). Biodiversity and ecosystem service conservation benefit when these indications of geographic origin include references to practices and places where specific commodities are produced in harmony with the environment.

Box 6.19: Geographical Indications for biodiversity conservation

Systems of Geographical Indications could be used to promote conservation of biodiversity. Cormier-Salem *et al.* (2010) assert that it has been used as a response to the problem of resolving both biodiversity erosion and local poverty, notably in countries such as in Senegal and Guinea Bissau. Though market-based incentives have been invoked by expert institutions e.g. the World Bank, International Monetary Fund, FAO, there is increasing acknowledgement by some policymakers of GI as potential policy tool to improve environmental incomes. Among these incentives, local speciality enhancement schemes are being implemented whether legal (i.e., fights against usurping of a product's name, counterfeiting, and the protection of intellectual property rights), commercial (i.e., eco-labelling, product promotion and livelihood improvement), and patrimonial (i.e., conservation of the various levels of biodiversity e.g. genes, animal species and vegetal varieties, ecosystems and landscapes, traditions and know-how). In general, however, these tools need to be applied cautiously and properly adapted to the needs of African nations. Countries could learn from the experiences of the South African wine industry (see Cormier-Salem, 1999; Barjolle et al, 2002; Jasanoff *et al.*, 2004; Roussel et al, 2007; Muchnik *et al.*, 2008; Cormier-Salem *et al.*, 2010).

For most sub-Saharan African countries, decentralisation policy is accompanied by a transfer of competences on the management of natural resources and the environment giving greater responsibility and power to local institutions. In Senegal, for example, local and regional authorities have been given the power to deliberate and recover the duties and taxes associated with the environment. This proximity management creates partnerships between local authorities and the private sector, which is now investing in conservation and human welfare. The strengthening of decentralisation stems from the political will to improve governance. Such political will has as its corollary the recognition of customary or traditional norms that more effectively protect wood, endangered species and forests, community heritage areas and other natural resources. Further information on the use of economic policy instruments to manage environmental degradation in Senegal is shown in Box 6.20.

Box 6.20: Policy instruments to manage environmental degradation in Senegal

Empowered by the decentralization process, the populations of the southern region of Senegal, for example, were the first to denounce the illegal and illicit exploitation of the forest resources of this part of the country. Most of the illegal exploiters came from The Gambia, where this activity is prohibited. The response of rural populations in Senegal reveals the need for subregional collaboration between countries. In terms of mineral resource exploitation in Senegal, the country uses a range of management tools such as quotas, licenses and permits (Bromley, 1991; Brooks *et al.*, 2001), which give rise to the payment of duties and taxes, and which limit respectively the quantities, the number of users and the rights of access and use of the resource. Currently, reforms are underway with respect to subsidies granted to mining companies and on improving transparency through the involvement of the local population and civil society in order to combat corruption and the acquisition of natural resources by foreign multinational companies.

Economic measures for biodiversity conservation must always be accompanied by broader supportive measures that reduce the ecological footprint through education, politics, information, awareness and social organisation (Bromley, 1991; Albers *et al.*, 1996; Jasanoff *et al.*, 2004; World Bank *et al.*, 2004).

They may encompass efforts through national and global processes relating to public sector management, macroeconomic and sectoral policy reforms, proactiveness in implementing environmental agreements and favourable donor arrangements to enhance the conditions of national and local economies (Costanza *et al.*, 1997; McNeely, 1993; Myers *et al.*, 2000; Bagnoli *et al.*, 2008). Equally important instruments to support economic incentive measures for biodiversity conservation include legal, policy, institutional and social measures, as well as agreements, enforcement, and accreditation (Bromley, 1991; Brooks *et al.*, 2001). Any instrument to incentivise or financialise biodiversity and ecosystem services needs to be as innovative and sensitive as possible in order to reduce conflicts between conflicting stakeholder interests, while constantly assessing impacts on biodiversity and ecosystem services.

6.5.2. Legal, regulatory and rights-based instruments

To ensure sustainable development, preserve biodiversity and improve the use of ecosystem services and quality of life, both national and international legal instruments should be used effectively (Prevoste *et al.*, 2016). Political interests at all levels play a major role in the formulation of laws and decrees creating protected areas and species, or instituting codes for biodiversity and ecosystem service protection. The State plays an important role, particularly since biodiversity often exhibits the characteristics of a public good (Aubertin *et al.*, 2009). Supporting legislation should be properly designed with the appropriate technical capacity to be able to establish protection objectives, reduce degradation and promote environmental improvements that are compatible with sustainable exploitation of natural resources and while ensuring compliance (Lamarque *et al.*, 1973).

There has been remarkable progress in the past 20 years in the development of environmental policies and laws in Africa, although strategies and levels of implementation within and between countries differ. Over 25 African countries now have constitutional provisions on the environment, while 43 countries have framework environmental laws (AMCEN, 2014a). Most of these countries have also developed tools and strategies to ensure that environmental laws are implemented.

A tight regulatory framework defining the scope and extent of resource use is a precondition for reversing biodiversity losses. At times such measures can be controversial though, as illustrated through reoccurring conflicts between the allocation of hunting permits and calls for hunting bans. Botswana banned hunting in 2014 and now has more than 230,000 elephants which many perceive as having negative impacts on agriculture and livelihoods (Mbaiwa, 2017). The ban on safari hunting resulted in the loss of income and jobs to the local communities, a loss of rural livelihoods, loss of game meat, increasing poaching incidents, negative attitudes towards wildlife conservation and land-use tenure changes (Mbaiwa, 2017).

Regulation remains the most widely used instrument for biodiversity and ecosystem protection. The regulatory toolkit includes a series of ‘command-and-control’ restrictions, mandatory requirements and procedures by government that directly limit certain actions or impacts and damages to threatened species. There are three basic types of regulatory instruments for biodiversity and ecosystem services:

- Management prescriptions for good practice in natural resource exploitation or regulation of emissions through emissions standards, ambient quality standards and technical standards;
- Restrictions on the use of products (e.g., illegally logged timber, activities damaging to endangered species etc.) or establishing production standards (certification, best practice codes etc.);
- Spatial planning which involves regulation of land-uses that have direct implications for ecosystem services or habitats.

However, regulation needs to be compatible with sustainable exploitation and comply with good practices, as well as connecting to conventions and agreements linked to laws at other levels, and key standards. For example, the ISO 14000 family of standards addresses various aspects of environmental management (NQA, 2017). It provides practical tools for companies and organisations to identify and control their environmental impact and constantly improve their environmental performance. ISO 140001, is a practical tool to help organisations identify and control environmental impacts and improve performance. This certification helps with environmental policy, sustainability, resource and asset management, legal compliance, carbon footprint and impact reduction, pollution prevention, corporate social responsibility, cultural awareness and change management, brand reputation (see https://www.nqa.com/en-us/certification/standards/iso-14001-2004). Another example is ISO 50001 (NRC, 2011), which provides organisations with a structured framework to manage energy such that it can increase energy efficiency, reduce costs and improve energy performance (see http://www.nrcan.gc.ca/energy/efficiency/industry/cipec/5379).

Laws and regulations further interface with rights-based instruments and customary norms. Nevertheless, while conservation projects target both ecosystems' and species' impacts on human well-being, in general, laws in Africa do not take a rights-based approach. This absence severely restricts community capacity to benefit directly and equitably from biodiversity through, for example, bioprospecting of plant species. It has been over four decades since the Kinshasa Resolution (1975) when African governments recognised the rights of indigenous communities and the importance of indigenous knowledge in natural resource conservation and management (Colchester, 2004). This resolution noted the importance of traditional ways of life and land ownership and called on governments to maintain and encourage customary ways of living. It urged governments to devise means by which indigenous peoples could bring their lands into conservation areas without relinquishing their ownership, use, and tenure rights. It also noted that indigenous peoples should not normally be displaced from their traditional lands in the establishment of protected areas, nor should protected areas be established without adequate consultation with the peoples to be directly affected. The same resolution was recalled in 1982 at the World National Parks Congress in Bali, Indonesia, which affirmed the rights of traditional societies to "social, economic, cultural, and spiritual self-determination" and "to participate in decisions affecting the land and natural resources on which they depend." The resolution advocated "the implementation of joint management arrangements between societies which have traditionally managed resources and protected area authorities (Colchester, 2004).

A further key step for Africa is found in the Swakopmund Protocol on the Protection of Traditional Knowledge and Expressions of Folklore within the Framework of the African Regional Intellectual Property Organisation, which was adopted in 2010 and entered into force in January 2012 (Colchester, 2004). It aims to: (a) protect traditional knowledge holders from any infringement on their rights as recognised within the protocol, and (b) protect cultural expressions against misappropriation, misuse and/or exploitation. The protocol employs a broad definition of traditional knowledge and folklore, along with a unique set of protections. Specifically, the holders of traditional knowledge under the protocol are deemed beneficiaries, and receive exclusive rights over the authorisation of use of their traditional knowledge, prevention of the exploitation of traditional knowledge without prior informed consent, the institution of legal proceedings to remedy infringements of rights protected under the protocol, and fair and equitable benefit-sharing arising from the commercial use of their traditional knowledge. Protocols such as this are vital for Africa, where traditional knowledge and indigenous and local knowledge remain important in the management of natural resources. Traditional knowledge and indigenous and local knowledge are examined in further in section 6.5.3.

6.5.3. Institutional aspects and social and cultural conditions

Institutions can be considered as constraints devised by humans to structure human interaction (North, 1994). Informal institutions are those that do not depend on the state for execution or enforcement (Colding *et al.*, 2001). They can include taboos and social norms. Informal institutions governing the use of environmental resources are present in many societies, and in certain conditions (relatively constant group membership, long-term residence in an area, and heavy reliance on natural resources) have led to the development of successful natural resource management (Ostrom, 1999; Jones *et al.*, 2008). The literature nevertheless suggests they can have both positive and negative impacts (Box 6.21, Box 6.22).

African societies have rich social and cultural norms, characterised by peaceful co-existing and high-value cultural traditions and institutions (see Chapter 1). In particular, many of the stories and narratives within African culture create a pathway for instilling environmental ethics and the communication of environmental values (Barau *et al.*, 2016), which in turn play an instrumental part in shaping informal institutions, behaviours and roles in society with regard to conserving biodiversity and ecosystems. An example is the 'Gali saree' or camel praise songs, embedded in many social norms, activities and routine daily life of Afar that teach and instil knowledge of nature, biodiversity and 'biophilia' or love for nature to young pastoralists, thereby contributing to positive community behaviours towards nature (Balehegn, 2016).

As globalisation processes have spread and property rights have followed a privatisation trajectory, social and cultural conditions and traditional institutions have changed, with the traditional organisation of African societies giving way to the state and the market (Box 6.23). The local social and cultural systems responsible for managing forests, biodiversity and ecosystems have consequently altered, with impacts on the sustainable management of biodiversity and ecosystem services and important consequences for the social and cultural context of governance and decision-making. In the African context, where people are closely dependent on biodiversity and ecosystem services for their everyday well-being, it is critical to incorporate indigenous and local knowledge in policy decisions around the management of biodiversity and ecosystem services to avoid such damage.

Many studies in Africa indicate the consistency and similarity of indigenous knowledge with scientific knowledge (Box 6.24). For instance, local knowledge was considered as effective as remotely sensed data in determining land-use and land cover changes, and in classifying land-use types in participatory GIS studies (Tripathi et al, 2004). Similarly, traditional drought forecasting in many African countries (Ziervogel *et al.*, 2010; Le Fur *et al.*, 2011; Chisadza *et al.*, 2015), was as effective as, and in some cases more effective, than scientific techniques (Balehegn, 2016). Del Rio *et al.* (2016) conducted participatory mapping of the Barotse floodplain and found a strong correlation between the indigenous and local knowledge typology and risk of crop failure to drought and to flooding demonstrating the clear functional basis for the Barotse typology originating from many generations of observation and experience. There are also findings that suggest that when communities monitor natural resources, their results are similar to those of scientists.

Box 6.21: Informal institutions and customary norms can have both positive and negative effects on biodiversity and ecosystem services

In Madagascar, 'Fadys' are systems of informal institutions that can make certain behaviours 'taboo' or forbidden, and are a strong part of Malagasy culture. They can vary from encouraging good manners, to strict rules linked to spiritual and ancestral beliefs and many are related to plant and animal species and natural resources (Jones *et al.*, 2008). Breaking fadys risks supernatural retribution, affecting individuals or leading to wider consequences; for example, a river drying up in western Madagascar was blamed on migrants breaking the fady banning pig farming in the region (Scales, 2012).

Fadys can protect endemic species and habitats: Jones *et al.*, (2008) concluded that in their study area in Eastern Madagascar, fadys provided significant protection to 5 species considered threatened according to IUCN. It is fady to kill many lemur species because they are believed to represent Malagasy ancestors, and fossa (*Cryptoprocta ferox*, Vulnerable) are fady to eat because they predate on lemurs i.e., eat the bodies of ancestors (Jones *et al.*, 2008).

When surveying hunting and consumption in Eastern Madagascar, Jenkins *et al.* (2011) found that species reported as fady to eat by a high proportion of respondents, tended to be eaten less frequently. Fadys may also offer protection to important habitats, with some areas of forest where people are not allowed to collect wood, clear forest or even travel through in cases where they contain family tombs (Scales, 2012).

However, fadys can also threaten wildlife: Beliefs that seeing an aye-aye (*Daubentonia madagascariensis*, Endangered) will result in sickness and death (Goodman, 2015) can lead to the killing those straying close to villages in parts of Madagascar. Little has been published on other fadys or cultural beliefs that may have negative outcomes for biodiversity, but there are particular snake species viewed as dangerous, despite not being venomous, and these can be killed out of fear (Tingle, 2012).

Over-reliance on informal institutions for biodiversity protection should be avoided: There can be a danger in relying too much on informal institutions alone for protection of biodiversity. Jones *et al.*, (2008) found evidence that fadys can evolve and change in response to economic drivers, e.g. a fady on selling wild-harvested species broke down in response to failed harvests. Jenkins *et al.*, (2011) documented increased in bushmeat consumption in eastern Madagascar, which included many typically fady species. Areas where consumption increased tended to have rapid recent immigration and economic development. Immigration leading to social change can weaken traditional beliefs (Jenkins *et al.*, 2013). Fadys may be very specific, only applying to certain people or areas. For example, Kaufmann (2014) found that a fady protecting radiated tortoises (*Astrochelys radiate*, Critically Endangered) was only prevalent in a few local villages, and the tortoises were still being killed in large numbers by other people passing through. Fadys may also break down where local people lose the right to manage their natural resources. After a clamp-down by park officials on tavy (slash and burn agriculture) in Ranomafana National Park, villagers were observed killing a radio-collared sifaka (*Propithecus edwardsi*, Endangered), which is normally fady to kill, in order to express their anger to park officials after being excluded from an area of forest (Jones *et al.*, 2008).

Box 6.22: The role of informal institutions in natural resource management

Institutions and traditions among Afar communities include: 1) the *Adda* or a traditional Afar ruling system, where knowledgeable elders called '*Asayamaras*', respected and trusted by the community, direct almost all parts of life of Afar pastoral communities (Hailu *et al.*, 2008); 2) The *Edo*, which is a traditional range scouting, is practiced whenever Afar pastoralists are faced with the prospects of unpredictable future weather'. The 'Edo's' or traditional rangeland scouts, usually strong young men of the village, who are sent to different places to collect information about weather, rangeland condition, local politics and other information relevant to the livelihoods of the pastoral communities (Tesfay *et al.*, 2004), and; 3) The '*Dagu'* is an effective and reputable traditional human based information and knowledge sharing network, through which anything anywhere that is relevant to the pastoral life of the Afar, is made to reach to relevant individuals and households (Yimer, 2013).

When any village or community in the Afar land is faced with the prospect of uncertain weather and a question of how to utilize and manage rangeland resources, information about future weather is collected from observation of biophysical entities and by traditional experts. The *Adda* elders also gather to discuss what to do on the basis of this information. They most commonly decide to send strong, experienced herders who are versed in the traditional techniques of weather forecasting to collect information about weather in far located rangelands (Tesfay *et al.*, 2004). The individuals sent for rangeland scouting (*Edo*) make detailed observations about the plants, soil, atmosphere, and the condition of animals in the far located areas they are visiting. All observations for special indicators such as special plants, insects, birds and environmental variables are made to come to conclusion about the possible near future weather conditions in the rangeland they are visiting. The individuals in the '*Edo*' make a detailed analysis of different observations to come up with a recommendation that they will report back to the *Adda* elders.

This is because they know their forests better from years of experience in using and managing them. However, this only applies when monitoring of forests is related to a local perspective (Danielsen *et al.*, 2014). Other studies have established discrepancies among the two knowledge systems e.g., in weather forecasting, (Ziervogel *et al.*, 2010; Simelton *et al.*, 2013; Chisadza *et al.*, 2015) and valuation of plant species (Balehegn *et al.*, 2015). Discrepancies can result from differences in the nature of the two knowledge systems (e.g., variables observed), the system and approach to the comparison, or inherent failure of one or both of the systems to actually depict or perceive reality (Balehegn *et al.*, 2015). Nevertheless, in many local settings, indigenous knowledge has been observed to be more practical, accurate, locally relevant in terms of scale and parameters, as well as more understandable, interpretable and affordable (Roncoli *et al.*, 2002). Most interesting however is the complementarity between the two knowledge systems, which facilitates a deeper understanding of the coupled interactions between nature and its contributions to people, and highlights the risks of decoupling indigenous and local knowledge and conservation.

Box 6.23: Multinational agricultural land acquisitions (land grabs) are leading to disappearance of the commons, local institutions, land degradation and other forms of injustices

The food, fuel and financial crisis of the mid-2000s has resulted in a global rush to purchase and lease fertile African land (Anseeuw, 2013). This explosion of commercial land transactions and land speculation has been dubbed by many as 'land grabbing' instead of the depoliticised term 'large-scale land investment' (Borras *et al.*, 2012). Africa has been the centre of most of the land grabbing that has taken place (Cotula, 2012). According to the Land Matrix report (Nolte *et al.*, 2016), 422 land deals have been concluded on the continent, covering 10 million hectares. An important issue with regard to land grabbing in Africa is that it is usually done based on arguments of unused land, no man's land or wasteland (Hall *et al.*, 2015). However, because of the nature of traditional land-use in many African indigenous communities being communal, rotational or pastoral, what appears to be unused, under-utilised, or ambiguously owned land in a given time may not be so (Geisler, 2012). The impetus to increase agricultural yield on the African continent has placed a significant proportion of natural habitats that have never been cultivated throughout history, into the category of cultivable or arable. Such labelling resulted in 30-40% of remaining forest in Central Africa to be under concession (Clark *et al.*, 2009). Therefore, it provides an additional impetus for justifying the leasing of 'low-productivity' communal lands to capital-intensive investors (Balehegn, 2015). Large-scale land grabbers (investors) usually fence their newly acquired land and physically exclude wildlife, livestock and local people, causing a breakdown of traditional strategies and utilization and ecological balance of the land, causing pressure on other areas. For instance, in the Gabmella regional state of Ethiopia, 90,000 households were relocated through resettlement and land investment displacements, resulting in a loss of traditional livelihood for over one million people and enormous ecological pressure on newly resettled areas (Horne *et al.*, 2011). Moreover, the way land deals are being implemented in different African countries is marred by corruption where local uses and issues of biodiversity protection are deliberately overlooked by officials in charge of the land deals (Cotula *et al.*, 2009). For instance, due to lack of legal provisions in the agreements, in Ethiopia large-scale investors (usually foreign) clear natural vegetation with machinery and then burn the cleared wood and debris, while small-scale local investors generally clear forest, convert it to charcoal and carry out the illegal, but lucrative business of charcoal selling (Horne *et al.*, 2011).

For example, such land grabbing, instead of fulfilling their intended objectives of local food production, has resulted in 7,100 ha of Mabria forest being cleared for sugarcane in Uganda. This clearance is predicted to threaten 312 plant species, 287 butterfly species and 199 bird species that are available in the forest (Senelwa *et al.*, 2012). Similarly, a leasing of an upstream water source in Tanzania has resulted in a pollution of water pollution affecting 45,000 local consumers (Arduino *et al.*, 2012).

Despite seemingly being ignored by many African nations, there are many global agreements that can be adopted and implemented for effectively curbing the impact of land grabbing on communities and biodiversity. New mechanisms designed to assist smallholder in accessing inputs and integrating into global commodity chains, of international regulations e.g. the European Union Renewable Energy Directives (Jacobsson *et al.*, 2009) and Renewable Fuel Standard program (EPA, 2010) should be encouraged. In doing so the host governments not only obtain the much sought-after cash and technology (through international land deals) but also will largely enhance the rehabilitation of abandoned or degraded areas. African states can also sign and strictly implement many international agreements and certifications that can guide responsible investment in land. Examples of such investments that can be applied based on the specific state of land and biodiversity in countries include: the Roundtable on Sustainable Palm Oil (Laurance *et al.*, 2010; Schouten *et al.*, 2011), Roundtable on Responsible Soy (Schouten *et al.*, 2012), Bonsucro certification and its local implementation (Moura *et al.*, 2012; Cockburn *et al.*, 2017), and the Soy Moratorium initiative (Leão, 2009).

It is repeatedly underscored that local experts' knowledge should be used as a supplement to or in hybridisation with scientific knowledge, or there should be co-production of knowledge while considering capacity building in conservation and natural resource management (Johannes, 1998; Mercer *et al.*, 2007; Glasson *et al.*, 2010; Silvano *et al.*, 2010; Tengö *et al.*, 2014; Pereira *et al.*, 2017; Stringer *et al.*, 2017). Although there is limited literature using the terminology 'Nature's Contributions to People (NCP)' as an alternative expression to facilitate consideration of plural knowledges about nature, African societies are inherently coupled to the environment, though this is not always emphasised. Figure 6.5 shows the combination or hybridisation of knowledge from different sources (indigenous, science and others) (Tengö *et al.*, 2014) alongside the key processes that can facilitate their combination (Stringer *et al.*, 2017).

Box 6.24: Linking scientific and indigenous knowledge

In Nigeria, Ayeni *et al.* (2016) showed a high consistency between indigenous people's perception of land cover changes, remotely sensed land cover products, and climate and surface water situations. Participatory approaches involving communities and local experts in assessing the impact of environmental change can, therefore, provide important insights into forest ecosystem services such as freshwater provision.

In Tanzania, Gaspare *et al.* (2015) compared traditional ecological knowledge with conventional scientific knowledge regarding the types of grouper (*Epinephelinae*), a fish species utilized by communities, and when they are caught. This information is of considerable value to fisheries managers and policy makers. Most of the resource-use patterns and effort exerted revealed in qualitative data collected about groupers on Mafia Island is consistent with that reported by Fischer *et al.* (1984). However, information on specific grouper species caught using 'nets' (as defined in this study) is lacking. In this case, fishers' traditional ecological knowledge is the only available source of information to complement conventional scientific data. The results indicated that confirmed scientific data and elicited knowledge that was new to both traditional ecological knowledge and science. It nevertheless highlighted some differences between traditional ecological knowledge and science (e.g. on spawning behaviour). Discrepancies in the two knowledge systems can be attributed to factors including observational scale differences, as well as methodological differences in gathering data (e.g. in sample sizes).

Such approaches to hybridising traditional knowledge and science/ technology enable the production of a knowledge system that is both locally relevant and scientifically accurate (Glasson *et al.*, 2010; Balehegn *et al.*, 2015). Hybrid knowledge systems that successfully incorporate both indigenous and scientific knowledge on an equal footing are very rare. However, some examples of inclusive or integrated knowledge system include the use of cyber tracker for biodiversity monitoring by Kalahari desert bushmen (http://www.cybertracker.org/) and the co-production of weather forecasting knowledge for training farmers and scientists to improve the accuracy of weather prediction at various scales (Zuma-Netshiukhwi *et al.*, 2013); combining indigenous and scientific knowledge for improved weather forecasting in Tanzania (Mahoo *et al.*, 2011), and the Nganyi project in Kenya (Ouma *et al.*, 2015), as well as the production of integrated knowledge (science and indigenous and local knowledge) for monitoring land-use and land cover changes in South Africa (Chalmers *et al.*, 2007). In Guinea, Le Fur *et al.* (2011) showed that ILK could complement scientific studies in describing the seabed, be used as a source of new scientific investigation, provide information on nursery location, and could substitute scientific surveys on fish diets provided the level of validity is identical, and constitute a satisfactory proxy for understanding trophic webs.

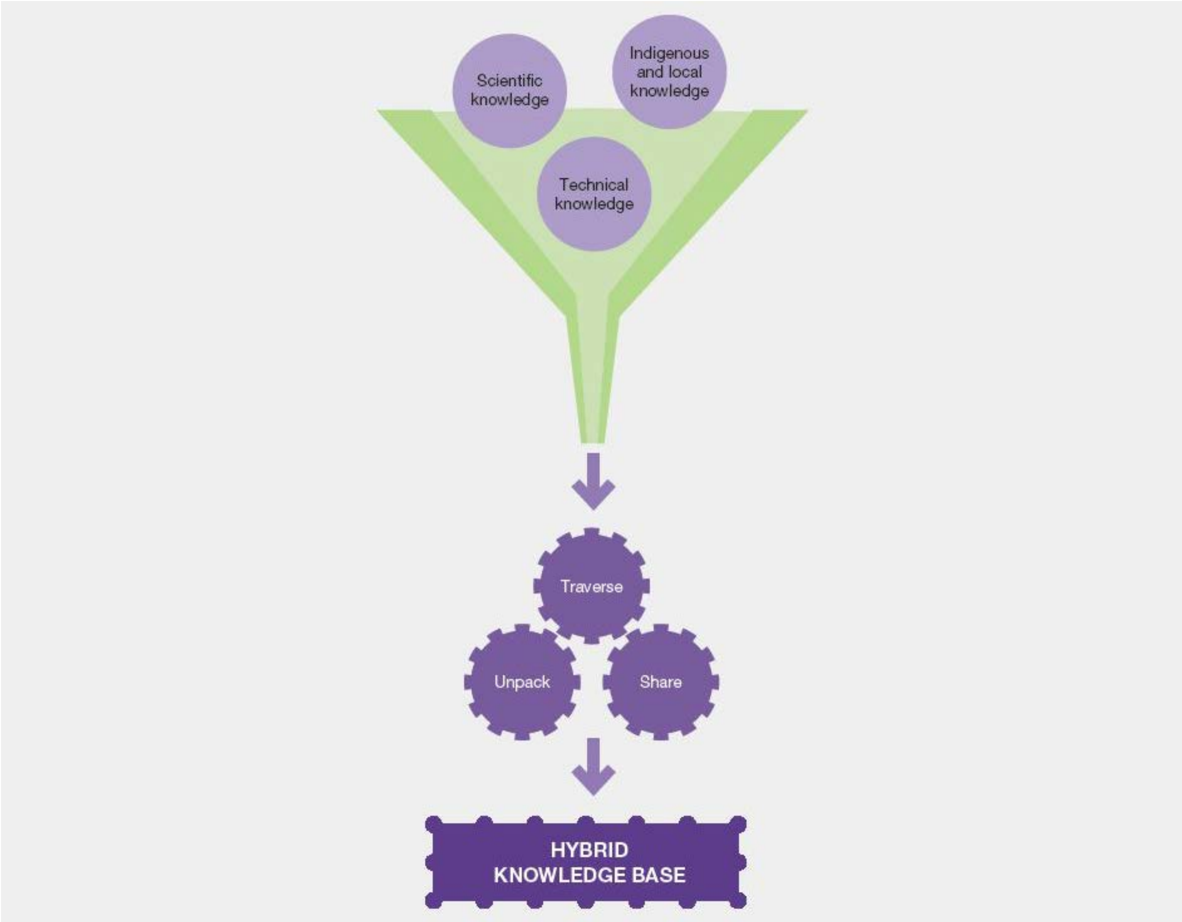

Figure 6.5: The combination or hybridisation of knowledge from different sources (indigenous, science and others) and the key processes that can facilitate their combination. Sources: adapted from Tengö *et al.* (2014); Stringer *et al.* (2017).

Such approaches can be extremely useful where capacity, data and resources are lacking, making the codification of local ecological knowledge highly practical (Johannes, 1998; Silvano *et al.*, 2010), particularly in fisheries studies for which the cost of obtaining data is an important consideration (Cury *et al.*, 2005; Garcia *et al.*, 2005). Local ecological knowledge could help to provide answers to questions relating to the identification of sensitive areas in terms of ecosystem productivity (Aswani *et al.*, 2004, 2006), for which diverse knowledge along entire coasts could be obtained.

Despite these advantages, a number of challenges remain in increasing the use of indigenous and local knowledge. There is a need for capacity building for those institutions tasked with the management of biodiversity and ecosystem services to identify and absorb relevant indigenous and local knowledge. Furthermore, it necessitates the fine-tuning of processes such as stakeholder engagement, participation, knowledge exchange and co-production, which are key vehicles for learning, information dissemination and communication. The importance of communication in the management of common assets such as biodiversity and ecosystem services cannot be over-emphasised. There are nevertheless suggestions that combining indigenous knowledge with western science would displace indigenous knowledge from its context or place-based significance, rendering it less useful (Tsegaye *et al.*, 2009). Moreover, there is widespread and steady inter-generational degradation of indigenous traditional knowledge in many

African communities. Therefore, indigenous traditional knowledge needs not only incorporation or hybridisation with science but also conservation in its own right (see chapter 1).

6.5.3.1. Multi-stakeholder governance approaches

6.5.3.1.1. Co-management

One increasing way of integrating different knowledge and stakeholder perspectives in Africa's polycentric governance context is through co-management approaches. Co-management refers to governance that is shared among stakeholders in diverse ways through decentralisation of power and decision-making. This kind of approach is increasingly seen in wildlife and fisheries sectors, as well as in the governance of transboundary resources. However, it is not yet fully utilised in the same ways as in other regions such as Europe (Stöhr *et al.*, 2014). In some cases, authority sits with a government agency that is required to engage or consult other stakeholders in decision-making, drawing on their knowledge and expertise (e.g., the Lake Chad Basin Commission and the East Africa Trans-Boundary Parks Authorities, amongst others). In other cases, multiple stakeholders (sometimes including local communities) participate in a management body that has responsibility for decision-making (e.g., Tanji Bird Reserve in the Gambia (Wicander, 2015)). In the Afar rangeland management process in Ethiopia, indigenous/customary institutions work side by side with government and religious institutions to solve and address conflicts arising from rangeland resource utilisation/sharing (Hailu *et al.*, 2008). Co-management approaches are particularly useful in areas where conservation and development objectives sometimes conflict, and can help to balance differing objectives. There are nevertheless critiques that many such institutional approaches, including those that are devolved to the local level, present social justice issues, in particular by insufficiently involving participation of groups such as women and youth (see e.g., Hope (2012) who provides a useful review of approaches to engage the youth in Kenya) and that they can reinforce elite capture.

Indeed, involving local communities in protected area co-management has increased globally, in order to minimise costs on local communities from conservation interventions. This sharing of power and responsibilities aims to increase legitimacy, inclusivity, representation and empower marginalised groups (Berkes, 2009). A global review of protected areas found that co-managed approaches were more likely to have positive outcomes for biodiversity and local livelihoods (Oldekop *et al.*, 2016). Yet other studies suggest that these approaches can be susceptible to elite capture, increasing inequalities and marginalisation of some stakeholders (Persha *et al.*, 2014). For example, a study in Madagascar found that households perceived limited benefits and high costs to participating in co-management, and an uneven distribution of these within and between communities. Poorer households and villages further from roads and markets were more likely to report costs to co-management (Ward *et al.*, 2018b). This highlights that to prevent exacerbation of pre-existing inequalities there is a need for co-management approaches to understand the heterogeneous nature of communities, and to ensure that involvement of local communities is representative and inclusive. Mechanisms that can help to reduce elite capture include safeguards such as waiving costs of fees and licenses for poorer participants in co-management (Blomley *et al.*, 2009).

6.5.3.1.2. Public-private partnerships

Another policy approach that requires institutional development involves public-private partnerships, which can be developed to address shared conservation and ecosystem service management goals (see also the example in Appendix 6.3). In Malawi, public-private partnerships were successfully used to reverse poaching, agricultural encroachment and deforestation in Majete wildlife reserve (Trimble, 2015). In 2003, the Malawian government awarded Johannesburg-based African Parks a contract to provide management expertise, as well as resources, equipment, and capacity building for the rangers. By the year 2015, about 2,559 animals including 217 elephants had been stocked into the reserve. The public-private partnership's success in this case is being used as a model for other reserves in Africa (Trimble, 2015). In another case, the Nairobi Water Fund brings together many partners and or stakeholders (e.g., the Nairobi City Water & Sewerage Company, Kenya Electricity Generating Company, Pentair Inc., Coca-Cola, East Africa Breweries Ltd, International Centre for Tropical Agriculture, The Government of Kenya, Water Resources Management Authority, Tana & Athi Rivers Development Authority, International Fund for Agriculture and Frigoken Kenya Ltd), to link upstream agricultural practices to downstream water quality. The Tana River supplies water to 95% of Nairobi's population, as well as another five million people living in the watershed. It supports important agricultural areas and provides half of the country's hydropower output. Deforestation and land-use conversion for agriculture have degraded natural areas that previously stored water, thus increasing runoff and soil erosion, reducing land productivity and increasing sediments in rivers, which affects water supplies. Management of the ecosystem services in this project includes a $10 million investment in water fund-led conservation, and intervention measures are expected to deliver $21.5 million in economic benefits over a 30-year timeframe.

However, public-private partnerships are not always effective, especially in cases where the private partner fails to keep their commitments and fails to understand local ethno-politics or does not craft a working relationship with local or indigenous communities. This is exemplified by the case of the African Parks Network in the Nech-sar and Omo National parks in Ethiopia, where the African Parks Network failed to make any investment in improving the condition of the park and local communities (Blonk, 2008). According to a local official in Ethiopia, African Parks Network's approach was described as 'exploitation of poverty in Africa' where the local population had little or no say in the fate of the parks, and usually had to move away, leaving communities feeling that animals are put above people to sustain the European myth of 'the wild', without allowing for human inhabitants and their livelihoods (Blonk, 2008). Lambooy *et al.*, (2011) identified a plethora of further challenges that limit the effectiveness of public-private partnerships in biodiversity conservation in Africa. These include lack of exchange of information and knowledge between the private sector and conservationists, high risks for private partners, high transaction cost for private partners, lack of management capacity and entrepreneurship among private partners, and very high transaction cost for private partners. It is therefore important that public-private partnerships in natural resource conservation start with the development of common understandings among government, local communities and other stakeholders, with each partner being open to compromise. Strong legal frameworks that can assure all parties are committed is a pre-requisite.

6.5.3.1.3. Community-Based Natural Resource Management

Many of the more devolved governance approaches can be broadly labelled as community management (e.g., community forests in Central Africa and communal lands in South Africa) or community-based natural resource management (often seen in Namibia, Botswana and Zimbabwe) (Ribot, 2003; Roe *et al.*, 2009). These approaches have increasingly been used in the agriculture, wildlife, forestry and fisheries sectors. Many African countries used wildlife protection and management as one of the community-based natural resource management goals. Community-based natural resource management passes decision-making authority over biodiversity and ecosystem services to local communities and can drive important institutional reforms and power redistributions (Roe *et al.*, 2009). Community-based natural resource management also theoretically provides a space for indigenous and local knowledge to have a greater influence (Gadgil *et al.*, 1993). Figure 6.6 sets out the core characteristics of community-based natural resource management.

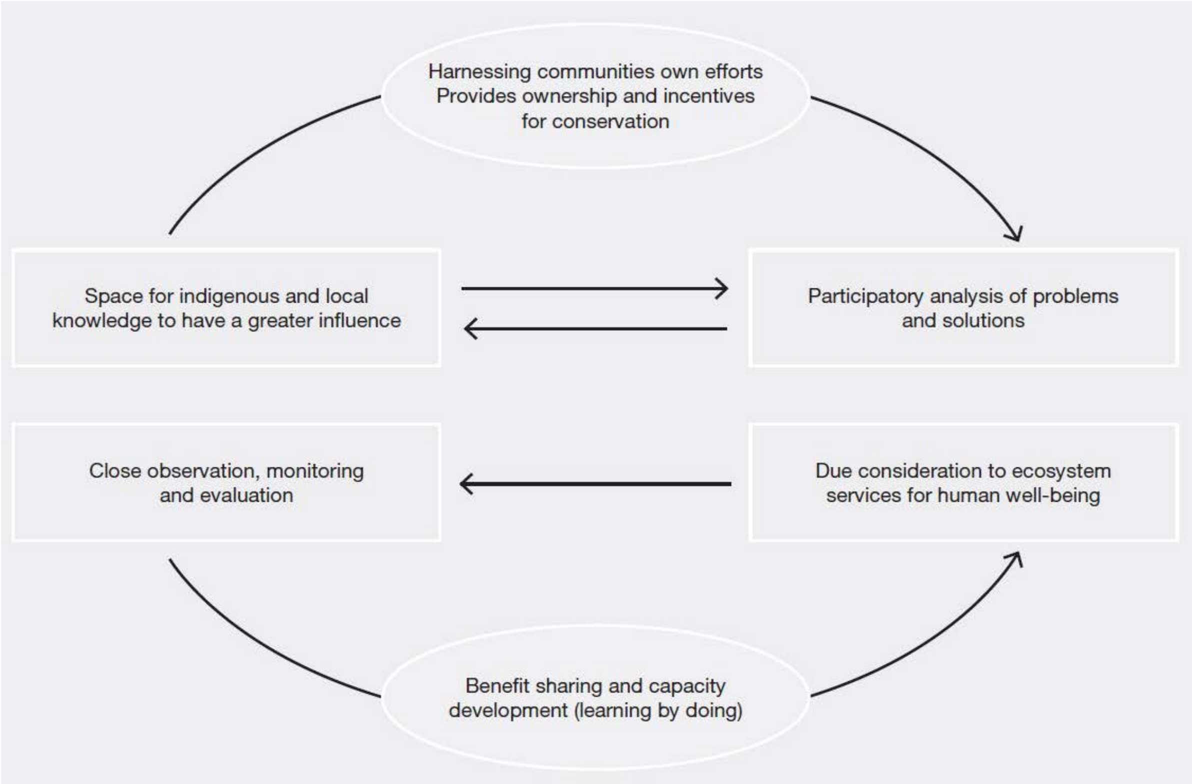

Figure 6.6: Characteristics of community-based natural resource management (CBNRM).

The literature presents a very mixed picture of the success of community-based natural resource management. In Tanzania, community-based forest management has been considered most effective because it provides sufficient incentives for communities to participate in long-term forest management. Community-based forest management has improved management of unreserved forests because villagers own the land and retain full rights to benefit from natural resources. Joint forest management initiatives in Tanzania, where central or local governments own land, perform slightly better than exclusive state-managed forests, though their viability remains uncertain. This is because joint forest management is considered restrictive and the guidelines on benefit sharing are vague, resulting in minimal transfer of benefits to communities and inequitable transfer of management costs to resource managers (Blomley *et al.*, 2009).

In Francophone West Africa, community-based natural resource management encompasses the Gestion de Terroirs approach, which links conservation with local development (Binot *et al.*, 2009). Positive reports about this approach come from the fan-palm ecosystems in Niger which support both agricultural and pastoral livelihoods, as well as providing provisioning and pollination services. Before the introduction of Gestion de Terroirs, the area was state managed, with few benefits gained by local communities. By developing a new institutional framework for community-based ecosystem management, which included establishing new management agencies, environmental protection crews and harnessing communities' own efforts, local incomes substantially increased due to improved palm wood marketing and employment in environmental protection, whilst, at the same time, resulted in the regeneration of more than 3,000 hectares of land (Binot *et al.*, 2009). In addition, cases of conservation such as Hirola in Kenya have been analysed and compared with other successful cases of community-based natural resource management around the world and it was found that all the successful cases have the commonality of being initiated by local communities themselves, and not by external pushes (Measham *et al.*, 2013). In the Hirola case which aims at conserving the last living representative of the *Beatragus* genus, one of the largest antelopes in Africa, the communities requested the establishment of the Hirola conservation programme. This community-driven programme has ensured the implementation of socially acceptable conservation measures. Pastoralists in eastern Kenya have been more supportive of several rangeland restoration practices which improve Hirola habitat alongside local livelihoods (Ali, 2016). This has ensured the willingness of communities to enact the measures required which emphasises the need for local ownership in conservation initiatives. When community-based natural resource management is initiated out of necessity by local communities, then, local communities use all resources at their disposal (including ILK) to spearhead the success of projects. This emphasises the need for local ownership and initiatives. When these factors are lacking, community-based natural resource management can fail.

Despite many positive reports in the literature, community-based natural resource management has drawn considerable critique (e.g., Logan *et al.*, 2002; Frost *et al.*, 2008; Shackleton *et al.*, 2010; Pailler *et al.*, 2015). For example, the establishment of new, decentralised committees can sometimes conflict with traditional community governance systems, as found in Benin and Swaziland (Stringer *et al.*, 2007; Mongbo, 2008). Conflicts arise due to the need to redistribute power and authority, but this is opposed by some groups at the local level, particularly if such redistribution challenges traditional structures and processes. These situations can be difficult to manage, particularly if older and younger generations take different positions.

Opportunities for harnessing local, indigenous and traditional knowledge are not always taken in community-based natural resource management. Despite theoretical possibilities that it offers improved involvement of indigenous and local knowledge, in most African countries, this continues to be only a claim devoid of practical implementation (Shackleton *et al.*, 2002). In many cases, the true and beneficial involvement of indigenous knowledge and indigenous people is recommended in some ideal or hypothetical situation where indigenous and local knowledge is said to be able to provide potential support, as opposed to actually being used (Davis *et al.*, 2003). This is mainly because of the nature of indigenous knowledge, which is abstract, subjective and authoritative; this makes it difficult to be amenable to established scientific methodologies and approaches (Cocks, 2006; Briggs, 2008). It is important to note that the losers in this are not only the indigenous African communities, who are deprived of opportunities for participation but also the resource management sector which misses the multifaceted benefits that could have been obtained by involving local and indigenous knowledge (Berkes, 2004).

Community-based natural resource management initiatives can also fail because their design and selection do not take into account financial viability, or insufficiently consider the costs of undertaking sustainable ecosystem management. This can be detrimental to local participation in projects which contain financial incentives as a design element. The Tchuma Tchato project, Mozambique, and the community-based natural resource management programme in the Kwandu Conservancy, Namibia, revealed that benefits were often deficient in value and volume. In addition, many households believed that benefits were inequitably shared (Suich, 2013). Effective stakeholder engagement is essential to ensure that relevant issues are included and addressed; as well as being cautious in that existing policies and instruments that are relevant for conservation will not always originate only from environmental policies, but might stem from different sectoral policies, e.g., agriculture and forestry, energy, transport or trade policy, and from local communities.

A growing number of positive examples of decentralisation and community-based management exist in Africa, even though cases of successful community-based natural resource management where indigenous and local knowledge has been integrated and utilised remain lacking (Measham *et al.*, 2013). Important lessons can be derived from community-based natural resource management projects in Africa for the governance of biodiversity and ecosystem services (Snively, 2012; Pailler *et al.*, 2015).

6.6. Creating an enabling environment for the governance of ecosystem services and biodiversity

Key to the development of appropriate policy mixes for the governance of the continent's biodiversity and ecosystem services is an enabling environment: "the combination of contextual elements allowing progress to be made towards a clearly defined goal" (Akhtar-Schuster *et al.*, 2011: 300). It is important to identify key determinants for the effective development, uptake and implementation of particular governance and institutional options, and understand the limitations to their effectiveness. This section assesses the importance of capacity (including resources) and tools, drawing on examples from across the continent.

6.6.1. Tools and methodologies supporting policy design

Policy making does not follow defined steps and is increasingly reliant on support tools and methodologies which can help both to build capacity and guide policy decision-making. In Africa, these include 'Biodiversity Monitoring Transect Analysis in Africa' which uses spatial data through GIS and remote sensing and scientific support to improve governance and conservation of Africa's biodiversity (http://www.biota-africa.org). Other tools used include the ones used by South Africa's biodiversity research group under the Council for Scientific and Industrial Research and departments of biological sciences in several universities across the country. Universities in the continent also use similar tools while other stakeholders engage in emerging platforms such as the Ecosystem-Based Adaptation for Food Security Assembly which was created following the unanimous adoption of the Nairobi Action Agenda and the constitution of the Ecosystem-Based Adaptation for Food Security Assembly by several stakeholders in 2015 (Box 6.25).

The IPBES (IPBES, 2016a; see also references therein) summarises seven families of policy support tools and methodologies according to their focus and use in: 1) assembling data and knowledge (including monitoring); 2) assessment and evaluation; 3) public discussion, involvement and participatory processes; 4) selection and design of policy instruments; 5) implementation, outreach and enforcement; 6) training and capacity building; and 7) social learning, innovation and adaptive governance. The availability and use of the best available data and information is critical in making policy decisions. Voluntary guidance meant to improve access to biodiversity-related data and information include[9]:

- use of common standards to enable integration and discovery of diverse data sets, government regulation and policy incentives to facilitate publication of publicly funded research and unrestricted access;
- digitisation of natural history collections;
- establishment of national biodiversity information facilities to promote coordination and sharing of data among stakeholders;
- enhancing capacity in biodiversity informatics through training programmes and through national, regional and global workshops, and collaboration through networks such as the Global

[9] See CBD/COP/DEC/XIII/31 (https://www.cbd.int/doc/decisions/cop-13/cop-13-dec-31-en.pdf)

Biodiversity Information Facility, as a means of increasing availability of data and filling knowledge gaps;

- public engagement in biodiversity observation through citizen science networks to enhance public awareness and to broaden the evidence base for research and decision-making;
- encouraging sharing of data obtained from the private sector;
- developing national platforms for data discovery, visualisation and use, e.g., through websites and portals;
- analysis of data and information gaps for prioritisation of new data mobilisation; and
- engagement with and support of both regional and global networks (e.g., the Global Biodiversity Information Facility, the Ocean Biogeographic Information System and the Group on Earth Observations Biodiversity Observation network for data mobilisation and access.

Box 6.25: The Ecosystem-Based Adaptation for Food Security in Africa assembly (EBAFOSA)

EBAFOSA is a tool aimed at promoting investments in ecological techniques that improve agricultural productivity without negatively affecting the ecosystem's capacity to sustain future productivity. EBAFOSA has provided a platform, in the 16 countries that have so far launched the framework, where stakeholders forge mutually benefitting partnerships aimed at upscaling ecosystem-based adaptation driven agriculture and its value chains into policy and implementation through country driven processes to ensure food security, climate adaptation and enhanced productivity of ecosystems. It has also focused on enhancing value addition to create income and job opportunities, especially for the youth who form 60% of the unemployed in Africa (Munang *et al.*, 2015).

In Cote d'Ivoire, EBAFOSA has helped establish partnerships amongst various actors in developing clean energy and markets to build on the 'Attieké d'Or' initiative to incentivise use of climate resilient, high-value cassava crop in all high potential areas—starting with the city of Divo and the Tonkpi Region. This has resulted in enhancement of biophysical & socioeconomic resilience at community level whilst contributing to economic growth (UNEP *et al.*, 2017). In Malawi, on the other hand, through EBAFOSA an inter-agency task force has been formed and it has identified key existing policies for amendment towards complementing establishment of Ecosystem-Based Adaptation agro-industrial zones that will be powered by clean energy (UNEP *et al.*, 2017).

In addition to tools and protocols on data-sharing, the tools developed under the Convention on Biological Diversity are used to assist countries and other stakeholders in conserving and sustainably using biodiversity. Greater application of these tools could be of significant help in safeguarding biodiversity and avoiding the worst impacts of its loss.

The analysis of tools and methodologies presented in this section follows a conceptual framework of the Integrated Policymaking cycle (UNEP, 2009) and IPBES conceptual framework (Díaz *et al.*, 2015). The Integrated Policymaking cycle identifies five steps in policy making and implementation: 1) Problem identification; 2) Policy formulation; 3) Decision-making; 4) Implementation; and 5) Monitoring and Evaluation.

6.6.1.1. Problem identification

As many countries in Africa are experiencing transitions in their demographic, urbanisation and economic development patterns (see Chapters 1 and 4), a careful policymaking approach is needed for

Africa's biodiversity and ecosystem services. Problem identification takes place in the context of public policy, covering issues, potential and current, which affect various stakeholders, and that can benefit from policy intervention (UNECA, 2015). Some of the most common tools and methods used to identify these problems include vulnerability assessments, the DPSIR framework, scenarios and other forecasting tools (e.g., see Chapter 5). DPSIR is an acronym for driving forces-pressure-state-impact-response and it has been used since 1995 by European environmental agencies to develop indicators, map causal relations and policy options (Maxim *et al.*, 2009). Vulnerability assessments have been carried out for decades in relation to poverty, natural hazards and more recently climate impacts (Kelly *et al.*, 2000). Vulnerability assessment, DPSIR and forecasting tools can take into account local perspectives in problem identification and can use participatory approaches.

6.6.1.2. Policy formulation

Policy formulation includes identifying public policy alternatives to address the problem of focus, and following selection processes that narrow the options to deliver the final policy solution (Hai, 2013). Market and non-market valuation methodologies play an increasingly important role in policy making, with the valuation methodologies typically presented in typologies (see Pearce *et al.*, 2002; World Bank *et al.*, 2004; van Beukering *et al.*, 2007). These also complement decision-support frameworks (e.g., cost-benefit analysis and multi-criteria analysis) with a number of appraisal techniques that can collect and analyse qualitative information (e.g., questionnaires, interviews, focus groups, citizen's juries, participatory appraisal, Q-methodology, expert opinions). The strength of multi-criteria analysis as a decision-making tool allows inclusion of a full range of social, environmental, technical, economic and financial criteria, and is different from the use of cost-benefit analysis which typically focuses on economic efficiency.

6.6.1.3. Decision-making

Decisions can both exacerbate and address environmental problems in Africa (Boon, 2015). Toth (2004) contends that decision-making needs to be underpinned by the use of the best available information about the biophysical characteristics of the ecosystem for which the decision is being made, their changes and their socio-economic effects, the social context and values with which the environmental problem is imbued, including cumulative and cross-scale effects. Environmental policy decision-making should be undertaken in a participatory manner involving local and indigenous communities (Dyer *et al.*, 2013; Leventon *et al.*, 2014) in line with principles of good governance. It also leads to enhanced trust between the different actors involved (de Vente *et al.*, 2016) and allows for the recognition of values, vulnerability concerns, cross-scale effects and context (Toth, 2004) and helps to identify and resolve trade-offs, leading to more just distribution of costs and benefits. It can also help to deliver implementation on the ground.

6.6.1.4. Policy implementation

The African Ministerial Conference on the Environment's Report (AMCEN, 2014b) on enhancing the implementation and effectiveness of environmental law in Africa, identified administrative, socio-economic and legal causes as drivers of low implementation, weak enforcement and the ineffectiveness of laws and policies implementation in Africa. Serious concerns are still being raised about how the capacity in the areas of planning and financial, human and technical resources will be addressed (AMCEN, 2014b).

In terms of capacity building, at a national and regional level, United Nations agencies and other global and regional partners, institutions and organisations have supported several African countries in the areas of environmental law and policy implementation. Capacity building for implementation takes place during the development of instruments like the National Biodiversity Strategies and Action Plans, National Biodiversity Reports, resource mobilisation strategies and several other national, regional and subregional projects focus on national capacity building and the establishment of institutions.

NEPAD's, Action Plan for the Environment Initiative contains a detailed implementation plan assigning institutions within the Africa Region roles and responsibilities (NEPAD, 2003). The Plan has costed activities which can be presented to potential funders. From the Action Plan, Africa Flagship projects have been developed. The flagships put conserving biodiversity and reducing ecosystem service loss as a priority (NEPAD, 2003).

6.6.1.5. Policy monitoring and evaluation

Various methods and approaches have been developed to monitor the impact of policies, to identify gaps and potential unintended consequences/side effects of policy interventions, and plan alternative mitigation actions to ensure the achievement of initial desired goals. Processes such as knowledge co-creation and co-production (Ayre *et al.*, 2015), and approaches such as participatory rural appraisal can provide useful inputs to the monitoring and evaluation process and facilitate assessment of progress towards desired future goals.

6.6.2. Capacity and resources

Governance of biodiversity and ecosystem services requires capacity (financial, institutional, technical, information and communication capacity) as well as processes such as stakeholder engagement, participation, knowledge exchange and co-production, capacity building and the indispensable people working in the various fields of biodiversity and ecosystem management (King *et al.*, 2007). Investments in these areas are particularly vital under options appropriate to less centralised governance contexts. Building capacity in the governance of biodiversity and ecosystem services requires the identification of new approaches and tools that are aligned to local knowledge.

Capacity to develop and implement policies for the management of biodiversity and ecosystem services is a baseline requirement for an enabling environment. Technical capacity (the knowledge, skills of individuals, access to tools and technology) is also important. In Africa, interdisciplinary studies and projects focusing on the deployment of science and technology, and the understanding and documentation of the state of biodiversity, have been undertaken mostly through State of the Environment reports and in some cases the respective Atlases. Resources (financial, human, technological including ICT and other innovations; indigenous and local knowledge) are also essential but in the African context are relatively scarce despite a growing number of data sources (Google Earth) and tools (InVEST, Rios, MESH) being open source and open access (see also chapters 1 and 5).

The effective management and governance of biodiversity and ecosystem services would greatly benefit from the availability of financial, human and technological resources (ICT and other innovations). Dependence on donor funding and project-based management usually does not lead to sustainability of project activities once the donor leaves or the project ends (Lambert, 2006). Emerging new financing mechanisms (environmental fiscal reforms, payment for ecosystems services, biodiversity offsets, green markets or markets for green products, biodiversity in climate change funding and biodiversity in international development financing) and the emphasis on biodiversity conservation practices will greatly enhance biodiversity and ecosystem services.

Identifying new approaches requires that African countries have knowledge on their actual financial needs in terms of how much is needed and where it is most needed. Financial assessments are used to determine exactly how much is required for biodiversity conservation and whether the investments made translate into positive conservation, ecosystem service, and well-being impacts. Botswana, Uganda, Zambia and a few other African countries are participating in a Biodiversity Finance Initiative, a new United Nations Development programme global partnership seeking to address the biodiversity finance challenge in a comprehensive manner, providing support for countries to enhance financial management for biodiversity and ecosystems. The initiative uses detailed country assessments of biodiversity policies, strategies and expenditure reports to inform development of biodiversity financial plans using innovative methodologies and consultations with national and global experts. These kinds of assessments are important for ensuring that countries are able to determine the existing resources and come up with innovative strategies for mobilising more resources for biodiversity and ecosystem services. For example, Uganda's Guidelines and Action Plan for Financing Biodiversity Conservation encourages the Government and stakeholders to utilise opportunities available within international and national regulatory and institutional frameworks to achieve optimal resource mobilisation for biodiversity conservation in the country. The action plans clearly indicate the amount of funding and the type of human resources required to achieve specific biodiversity and ecosystem services goals. It establishes a resource mobilisation focal point responsible for executing actions to generate the resources and ensures local communities are involved in the process (NEMA, 2015). If this is replicated in other African countries, it could create effective resource mobilisation actions and allow for redefining approaches to biodiversity and ecosystem services.

Capacity is also needed for policy implementation. A national level approach has been driven forward by the United Nations Development Programme and Global Environment Facility through National Capacity Self Assessments in 146 countries. Egypt, for instance, assessed its implementation status of United Nations Convention to Combat Desertification, United Nations Convention on Biological Diversity, and United Nations Framework Convention on Climate Change from 2005 to 2008. Capacity constraints were identified in order to prioritise action with regards to the Rio Conventions (Bellamy *et al.*, 2010).

The next section focuses on scenarios as tools for decision-making which can effectively harness existing capacities and resources, and be used at various stages in the policy cycle to inform decision-making by exploring options and alternatives.

6.7. Scenarios as tools for decision-making

Scenario analysis and modelling have been suggested as important policy support tools for enhancing decision-making about the longer-term future, especially given the uncertainty in social-ecological systems (see Chapter 5 of this assessment; MA, 2005; Vervoort *et al.*, 2014; WWF-AfDB, 2015). Scenarios can be used to guide specific planning and policy development by testing assumptions and generating new policy ideas (Vervoort *et al.*, 2014; Figure 6.5). The inherent uncertainty and diversity of potential futures are challenging for designing policies. Policy options are only a first step toward acting on the insights generated by the scenarios (UNEP, 2016). Because a set of scenarios offers the opportunity to explore diverse future contexts, each with their own challenges and possibilities, they can be used to make elements of plans more robust (feasible under future conditions) and/or adaptable to future eventualities.

Scenarios are distinguished from other approaches for future decision-making, such as forecasting and risk assessment, by being specifically intended for situations in which the factors shaping the future are highly uncertain and largely uncontrollable (Peterson *et al.*, 2003, Biggs *et al.*, 2007). The main goals of using scenarios in assessments of biodiversity and ecosystem services and their contributions to human well-being are to synthesise knowledge and advance systems understanding; to alert decision-makers to undesirable future impacts of global changes such as habitat loss and degradation; to provide decision support for developing adaptive governance strategies; and to explore the implications of alternative social-ecological development pathways and policy options (IPBES, 2016b).

The IPBES Methodological Assessment Report on Scenarios and Models of Biodiversity and Ecosystem Services (IPBES, 2016b) highlights the important role that scenarios play in the decision-making process. Figure 5.1 shows that scenarios are helpful across the four major phases of the policy cycle relating to agenda setting, design, implementation and review. However, as highlighted by Chapter 5 (Section 5.2.2) most regional scenarios developed for Africa are 'exploratory scenarios' (80%) that explore plausible futures. Of those scenarios included in the assessment, 17% of them were policy screening, however, only 6% were target-seeking and only 1% represented retrospective evaluations of a policy (Section 5.2.2). An example of a policy screening scenario makes use of a global agricultural land-use model that was developed under two forest conservation scenarios reflecting two different policy goals, namely: maximising forest carbon storage and minimising impacts on agricultural production (Krause *et al.*, 2013). The results of these scenarios show that conserving undisturbed natural forest appears to be a low-cost option for reducing greenhouse gas emissions. There are no other regional scenario exercises that explicitly deal with testing policies—either through a target-seeking, policy-screening or retrospective policy evaluation process.

6.7.1. Policy implications under the different scenario archetypes

Chapter 5 of this assessment outlines five scenario archetypes (Fortress World, Market Forces, Policy Reform Local Sustainability, Regional Sustainability) and analyses how achieving specific biodiversity, ecosystem services and development targets in Africa can be enabled under the contextual assumptions of these 5 archetypal futures (Box 5.2, Section 5.7 and Table 5.7.). Potential governance responses under these archetypes are discussed in Table 5.6. The following section highlights some implications for policy making based on these archetypes, linking more specifically to key policy goals that relate to biodiversity and ecosystem services in Africa (Table SPM 2, Table SPM 4, Table 5.7, Figure 6.7 below). The majority of the assessment undertaken in Chapter 5 used six core studies for the assessment, including: to a lesser extent, the Intergovernmental Panel on Climate Change's (IPCC) climate change scenarios (Nakicenovic *et al.*, 2000; Moss *et al.*, 2008, 2010; Kriegler *et al.*, 2010; van Vuuren *et al.*, 2012); the Millennium Ecosystem Assessment (MA) Scenarios (MA, 2005); the Global Environment Outlook 4 (GEO-4) global assessment (UNEP, 2007); and the World Wide Fund for Nature (WWF) Ecological Futures scenarios (WWF-AfDB, 2015) that were specifically developed for Africa and also used in the sixth Global Environment Outlook (GEO-6) regional assessment (UNEP, 2016) (Section 5.3).

6.7.1.1. Policy reform

Under this type of future there is an increased need for proactive legal and regulatory instruments (e.g., Protected area zoning, access and benefit sharing legislation; see also section 6.5.2) and economic and financial instruments (e.g., certification schemes, carbon taxes; see section 6.5.1) that mediate the impacts of intensive agriculture, extractive industries and associated infrastructure (e.g., transport, water and energy). Policy reform envisions a more globally connected world where local economies are boosted and policies aligned with a green economy can potentially flourish, relieving pressure on marine resources which aligns with enhancing Sustainable Development Goal 14: Life below water

(WWF-AfDB, 2015). Protected areas increase based on the political recognition that healthy ecosystems underpin development, however biodiversity outside these protected 'islands' declines. Trade-offs between some of the ecosystem services linked to Sustainable Development Goals (e.g., Sustainable Development Goal 2: Zero hunger and Sustainable Development Goal 6: Clean water and sanitation) and Aichi Biodiversity Targets (e.g., Target 5: Reduce habitat loss and degradation) are the most apparent related to these scenario types. Decision-makers in Africa under this scenario need to pay careful attention to tele-coupling, for example, the impacts of biofuels grown locally for foreign markets (Liu *et al.*, 2013) or diversion of river flows benefiting global markets at the expense of local livelihoods (Bohensky, 2006). Policies need to be proactively put in place to mitigate potential sustainability challenges associated with these transnational deals promoting Sustainable Development Goal 12: Responsible consumption and production.

While development under these scenarios is mainly at the expense of the environment, an African future under policy reform aligns well with the key targets of the New Partnership for Africa's Development and Blueprint for an Integrated Approach to implement Agenda 2063, and can potentially rapidly achieve some of the development objectives as there is slow population growth and strong policies which can help to reduce poverty (Sustainable Development Goal 1: No poverty) and inequality (Sustainable Development Goal 10: Reduced inequalities) and invest in public goods (Sustainable Development Goal 4: Quality education and infrastructure Sustainable Development Goal 9: Industry, innovation and infrastructure). Under policy reform, rapid technological development increases access to water by as much as 3 fold (Alcamo *et al.*, 2005). However, this comes with a projected 3–5 fold increase in waste-water discharge in sub-Saharan Africa, which will require additional policy and infrastructure interventions to ensure that poor water quality does not impact on human and environmental health (Alcamo *et al.*, 2005; MA, 2005). Policies that promote spatial and cross-sector investment and planning can minimise the impacts large-scale infrastructure development has on ecosystems, especially with the risk of climate variability. This scenario focuses on building resilience by encouraging policies that promote economic diversification and reduce market failure, but at the same time needs to strengthen environmental regulation to avoid the dependence on a few resources that can rapidly be depleted (Alcamo *et al.*, 2005). Under policy reform, governments actively work together with the private sector and civil society to co-develop new policies to strengthen economic growth (UNEP, 2007). It is vital that indigenous knowledge is integrated into this cooperation (see also section 6.5.3.1 on multi-stakeholder governance).

6.7.1.2. Market forces

In this scenario, economic development in Africa is most rapidly achieved under a market forces scenario based on policies which create open markets and see the government and private sector promoting the exploitation of the abundant natural resource base for global trade (Nakicenovic *et al.*, 2000; UNEP, 2007, 2016; van Vuuren *et al.*, 2012; WWF-AfDB, 2015). While there is also rapid technology development, there are limited investments in alternative energy and as nations abandon their climate agreements (which is at odds with Sustainable Development Goal 13), fossil fuels are used intensively to power development (Nakicenovic *et al.*, 2000; UNEP, 2007; van Vuuren *et al.*, 2012). Rapid economic growth can potentially benefit many people in the short-term, with inequality lessening (see section 5.5); promoting Sustainable Development Goals 1, 3, and 10. However, unless there are efforts from decision-makers to strengthen policies which promote ecosystem stewardship aligned with global conventions (e.g., Strategic Goal A–C of the Aichi Biodiversity Targets and Sustainable Development Goals 6, 12, 14 and 15) there may also be rapid ecosystem transformation. Such transformation places long-term sustainable development, based on extractive industries, in jeopardy, and could fuel tensions between the private sector and local and indigenous communities (UNEP, 2016).

To mitigate these negative impacts on local livelihoods, policy options that address issues related to weak centralised governance, limited environmental regulation, illegal or unsustainable harvesting or poaching are needed. Such options include adaptive governance and co-management (see sections 6.1 and 6.5.3.1). More innovative governance partnerships which include those between business, communities and government are needed to strengthen the resilience of infrastructure and spatial planning processes (Sustainable Development Goals 16 and 17). Here, policies linked to Strategic Environmental Assessments can be helpful as they can mediate potential conflicts between resource users and assist in mitigating the impacts of future global economic and climate variability (WWF-AfDB, 2015; UNEP, 2016). Strong cross-sectoral, national frameworks for regional and international trade agreements with a foundation of policies that incentivise the maintenance of ecological functions can potentially fast-track sustainable development, especially in areas with limited regulatory capacity (e.g., Box 6.16, East African example of Payment for Ecosystem Services in Appendix 6.3). Strong economic growth enables more equitable division of resources and together with slower population growth results in communities that are less vulnerable to the impacts of climate change (van Vuuren *et al.*, 2014).

6.7.1.3. Local Sustainability

A future under a local sustainability scenario favours policies that proactively facilitate environmental protection, social equality and human well-being at local levels (MA, 2005; UNEP, 2016). This type of future is aligned with multiple Sustainable Development Goals, especially since development activities will be implemented at national and local levels. This archetype enables the most rapid advancement towards to Aichi Biodiversity Targets (especially targets 5, 7, 11 and 14) and the United Nations Convention to Combat Desertification, aligned to Sustainable Development Goal 15. It is further associated with a reduction in habitat loss due to an assumption of low population growth and eventual adoption of sustainable practices. Proactive policies linked to reforestation see the expansion of forest cover by 2100 on the whole (Nakicenovic *et al.*, 2000, scenario B2). Agriculture is localised, cooperative and governed through participatory decision-making processes, however, these small-scale agricultural areas are fragmented and degradation continues outside these areas. Cumulatively the impacts of small-scale agriculture’s effects on regional sustainability need consideration, alongside coherence in local land management, particularly when also addressing impacts that disasters (e.g., droughts or conflict) might have beyond the local scale. Policies focusing on investment mechanisms that enable financial and technical support for local ecosystem-based schemes (e.g., payments for ecosystem services) which link to international markets can strengthen more sustainable development in Africa (WWF-AfDB, 2015). Harnessing capacity and resources from key international organisations like the Consultative Group on International Agricultural Research and its various programmes, especially that on Water, Land and Ecosystems, African institutions like NEPAD and the African Union as well as subregional organisations like the Central African Forest Commission, to strengthen local institutions and empower local stakeholders with planning tools and technology, is critical for endogenous, equitable development in Africa. A focus on regional network weaving and integration of efforts is especially critical to ensure alignment with the aspirations of Agenda 2063. Policies which favour decentralised governance mechanisms and align with international frameworks (e.g., Sendai framework for Disaster Risk Reduction 2015–2030 (UNISDR, 2015) can assist with balancing trade-offs associated with agriculture and human settlements on ecosystems and enable more resilient futures, especially in the light of changing climates.

6.7.1.4. Fortress world

A future which focuses on strengthening regional and local identities through strong national governments with the main objective to strengthen security is still a plausible trajectory for Africa (Nakicenovic *et al.*, 2000; MA, 2005; UNEP, 2007). Within this scenario, environmental policies are mostly reactive and geared towards facilitating regional economic growth and there is rapid population growth. Under a fortress world future, habitat loss, mainly due to policies which promote extensive agriculture, are the highest relative to other scenarios, resulting in limited ability to achieve multiple Aichi Biodiversity Targets (targets 5, 7, 12, 15) and those Sustainable Development Goals strongly associated with maintaining ecological integrity (Sustainable Development Goals 11, 14, 15). Under this scenario, countries endowed with high levels of biodiversity and ecosystem services are able to develop faster, increasing species loss and local extinction rates (at odds with Biodiversity Target 12). There are few policies promoting inter-regional trade and the government and the private sector compete for control, with the elite remaining powerful and poverty worsening in many communities (impacting Sustainable Development Goal 10). Under this scenario, which envisions fragmented and slower per capita growth and technological change (Nakicenovic *et al.*, 2000) with associated lower carbon emissions, policies are needed around climate adaptation as there is limited adaptive capacity to address existing climate-related impacts (limited action on Sustainable Development Goal 13) (van Vuuren *et al.*, 2014). Similarly, policies are needed that improve catchment management practices such as better regulation and application of agrochemicals under agricultural intensification, combined with riparian forest conservation to reduce the risk of runoff-driven water pollution (limiting Sustainable Development Goals 6 and 2).

6.7.1.5. Regional Sustainability

In this scenario the future of Africa is based on policies which support intra-regional trade for development with the main objective to contribute towards global or regional sustainability. There is an emphasis on evidence-based policy making with strong, capacitated regional governance systems and a focus on policies linked to strategic planning and implementation of infrastructure that has limited impact on sensitive ecosystems (e.g., Strategic Environmental Assessments and Environmental Impact Assessments) (WWF-AfDB, 2015). Technology advances are rapidly directed towards more proactive environmentally friendly practices (Sustainable Development Goal 12) with high land productivity from often engineered ecosystems (MA, 2005; UNEP, 2007) and lower carbon emissions (contributing to Sustainable Development Goals 2, 13) (Nakicenovic *et al.*, 2000; van Vuuren *et al.*, 2014) allowing for improved mitigation and adaptation of climate change. While the needs for increased infrastructure to support development increase, there is strong transboundary collaboration, investment and cooperation, aligned with national priorities. These aspects facilitate development in a more equitable manner (Sustainable Development Goals 10, 16) and permit resources to be used more efficiently (WWF-AfDB, 2015). In this scenario, regions work together to improve human well-being and ecosystem resilience (UNEP, 2007). However, success of this scenario is undermined if policies promoting conservation and infrastructure development are not aligned and well-coordinated with each other.

6.7.2. Governance responses under uncertain futures

There is a need to avoid duplication of effort, refrain from competition for the same resources, enhance efficiency, and instead to tap into the potential for shared knowledge management to harness co-benefits and reduce trade-offs. Such efforts require consideration of policy and institutional interplay, both at and across different scales and levels of governance (Young, 2002; Oberthür *et al.*, 2006). The key take-away policy implications from looking at the scenarios are that it is necessary to have a suite of responses available and that there is no ideal policy pathway that is any better than any other. Rather, it is important to ensure that policies are synergistic and coherent, where relevant and appropriate, and that one policy is enabled to make up for the weaknesses inherent in another policy.

As described in section 6.5, an array of policy instruments is available to enhance the opportunities from, and address the challenges associated with, biodiversity and ecosystem services. These instruments include legal and regulatory instruments (e.g., environmental legislation, protected area establishment, land suitability zoning, and access and benefit sharing legislation), rights-based instruments and customary norms (e.g., access and benefit sharing legislation, particular land ownership and tenure), economic and financial instruments (e.g., taxes and charges), and social and cultural instruments (e.g., precedence or lack thereof over formalised legal systems). Such policy instruments can either be applied independently or in combination. Building on Table 5.7 in Chapter 5, Table 6.2 provides examples of policy instruments for addressing the combination of the Sustainable Development Goals and Aichi Biodiversity Targets under the African Union’s Agenda 2063 aspirations. In this table, based on a combination of expert opinion and available literature, some examples of potential policy instruments that could be useful in meeting these biodiversity and ecosystem services and development goals are provided. Whilst all policy needs to be context specific, here, the emphasis is placed on those instruments that target sustainable development more widely and that are attuned to Africa’s social-ecological heterogeneity.

Table 6.2: A non-exhaustive set of policy instruments to address an integrated set of environmental and biodiversity goals for Africa.

POLICY GOALS				POLICY GOALS		
Agenda 2063 Goals	Aichi Biodiversity Targets		SDGs and Targets	Legal-Regulatory	Economic-Financial	Socio-Cultural
3 Healthy, well-nourished citizens	14	Ecosystem services	1 **No poverty** (Target 1.4) 2 **Zero hunger** (Target 2.3) 3 **Good health and well-being** (Target 3.3) 5 **Gender equality** (Target 5.A)	Food security policy, food safety, pro-poor and gender sensitive development strategies, land tenure system, right to food, right to healthy environment, indigenous people's rights	Payment for Ecosystem Services (PES), eco-labelling	Livelihood policy, social protection, pro-poor and gender sensitive development strategies
5 Modern agriculture for increased productivity and production	7	Sustainable agriculture, aquaculture and forestry	2 **Zero hunger** (Target 2.3, 2.4, 2.A) 12 **Responsible consumption & production** (Target 12.2, 12.3) 15 **Life on land** (Target 15.2, 15.B)	Land zoning, land tenure, protection of indigenous land, indigenous intellectual property rights	Smart agriculture, agricultural green economy, correct and prevent trade distortions in world agricultural markets, financial incentives, value addition, eliminate agricultural export subsidies, index based livestock insurance for pastoral people	Public works programmes, risk insurance index, integration of indigenous and local knowledge for better and adoptable technologies, indigenous knowledge and biodiversity: bio-prospecting
6 Blue ocean economy for accelerated growth	6	Sustainable management of aquatic living sources	2 **Zero hunger** (Target 2.3) 14 **Life below water** (Target 14.2, 14.4, 14.7, 14.B, 14.C)	Marine protected areas	PES, elimination of perverse incentives, taxes	Livelihoods and development strategies
7.1 Sustainable natural resource management	8	Pollution reduced	3 **Good health & well-being** (Target 3.9, 3.11) 6 **Clean water & sanitation** (Target 6.3) 11 **Sustainable cities & communities** (Target 11.6, 11.8) 12 **Responsible consumption & production** (Target 12.4) 14 **Life below water** (Target 14.C)	Bans (e.g. on plastic bags), pesticide and fertiliser regulations, enforced air and water quality regulation to reduce pollution-induced mortality and contamination	PES, elimination of perverse incentives, taxes or 'polluter pays' principles	Awareness and skills development, protection of indigenous land
	9	Invasive alien species prevented and controlled	15 **Life on land** (Target 15.8)	Biocontrol regulations, biosafety protocols, early detection and rapid response, risk analysis and risk assessment, eradication protocols, permits, indigenous people's land protection	Fees, elimination of perverse incentives, taxes	Working for water: government jobs for environmental jobs, raise awareness of impacts of invasive species

POLICY GOALS			POLICY GOALS		
Agenda 2063 Goals	**Aichi Biodiversity Targets**	**SDGs and Targets**	**Legal-Regulatory**	**Economic-Financial**	**Socio-Cultural**
7.2 Biodiversity conservation, genetic resources and ecosystems	Safeguarding genetic diversity	2 **Zero hunger** (Target 2.5) 15 **Life on land** (Target 15.6)	Access and benefit sharing legislation (e.g. Nagoya Protocol), protection of indigenous knowledge and seed exchange processes, participation in national and international gene banks		Community gene banks, seed stores
	Habitat loss halved or reduced	14 **Life below water** (Target 14.C) 15 **Life on land** (Target 15.1, 15.2, 15.5)	Strategic environmental assessment regulations (incl. EIA), support creation, management and benefit-sharing of natural ecosystems outside of areas	Conservation offsets, environmental easements, PES, REDD+, resource use fees, transparent financial accounting, taxes, natural capital accounting, ecotourism	Participatory approaches for natural resource management, social forestry, REDD+, indigenous people's land protection
	Reducing risk of extinction	15 **Life on land** (Target 15.5, 15.7, 15.12) 16 **Peace, justice & strong institutions** (Target 16.4)	Hunting quotas and permits, hunting bans, NBSAPs, gene banks, indigenous people's intellectual property protections	Conservation offsets, environmental easements; PES, REDD+, resource use fees, transparent financial accounting, taxes, natural capital accounting, ecotourism	Herbaria, zoos, and gene banks
	Protected Areas	8 **Decent work and economic growth** (Targets 8.3, 8.9) 11 **Sustainable cities & communities** (Target 11.4) 14 **Life below water** (Target 14.2, 14.5) 15 **Life on land** (Target 15.4)	Protected area legislation, access and use rights, protections of indigenous and ancestral land rights, protection of traditional lands	Conservation offsets, environmental easements; PES, REDD+, resource use fees, transparent financial accounting, taxes, natural capital accounting, ecotourism	Participatory approaches to natural resource management, social forestry, REDD+, indigenous peoples' land protection
7.3 Sustainable production and consumption patterns	Sustainable production and consumption	6 **Clean water & sanitation** (Target 6.4) 9 **Industry, innovation & infrastructure** (Target 9.4) 11 **Sustainable cities & communities** (Target 11.6, 11.A) 12 **Responsible consumption & production** (Target 12.2 – 12.7) 14 **Life below water** (Target 14.10)	Policies to decouple environment from economic growth	Certification, taxes, incentives to reduce food waste and loss	Public Private Partnerships (PPPs)
	Awareness of biodiversity increased & Biodiversity values integrated	4 **Quality Education** (Target 4.1, 4.7) 11 **Sustainable cities & communities** (Target 11.7) 12 **Responsible consumption & production** (Target 12.8) 13 **Climate action** (Target 13.3) 15 **Life on land** (Target 15.9)	Urban planning, 'polluter pays principles', rewarding best practice for sustainable development and sustainable production and consumption	Certification schemes, taxes, financial incentives, PES	National curriculum, PPPs, corporate environmental and social responsibility and accountability, indigenous peoples' property rights protection

POLICY GOALS				POLICY GOALS		
Agenda 2063 Goals	Aichi Biodiversity Targets		SDGs and Targets	Legal-Regulatory	Economic-Financial	Socio-Cultural
7.4 Water security	14	Ecosystem services	1 **No poverty** (Target 1.4) 5 **Gender equality** (Target 5.A) 6 **Clean water & sanitation** (Target 6.1 – 6.8) 15 **Life on land** (Target 15.4)	Transboundary water agreements, national water programmes, integrated water resources management, right to access to water, including that of indigenous peoples, protection of areas of culturally important areas	PES for water quality, watershed protection, taxes, water accounts	Community watershed management, ensured access to water
7.5 Climate resilience and natural disasters preparation and prevention	15	Ecosystem restoration and resilience	11 **Sustainable cities & communities** (Target 11.5, 11.9) 13 **Climate action** (Target 13.1) 15 **Life on land** (Target 15.1, 15.3, 15.4)	Disaster risk reduction strategies (e.g. flood and fire), early warning systems, restoration programme	Climate offsets	
	10	Ecosystems vulnerable to climate change	1 **No poverty** (Target 1.5) 13 **Climate action** (Target 13.2) 14 **Life below water** (Target 14.2, 14.3)	Climate change policy, environmental impact assessments, policy instruments for indigenous people's risk reduction, agricultural policy supporting food system resilience	REDD+, national adaptation plans, climate change investment plans, clean development mechanism, carbon offsets, carbon credits, green climate fund, climate change adaptation fund	Community-based adaptation, ecosystem-based adaptation, access and benefit sharing, indigenous knowledge systems
7.6 Renewable energy			7 **Affordable & clean energy** (Target 7.1 – 7.5) 9 **Industry, innovation & infrastructure** (Target 9.4, 9.A)	Renewable energy policy, integration of renewable energy, affordability and accessibility into development programmes, energy efficiency standards	Emissions trading, carbon taxes and payments, elimination of perverse incentives, technology transfer (agreements), life cycle analysis, internalization of environmental and social costs	Capacity and skills development

6.8. Conclusion

This chapter has assessed existing policies and governance options and actions in response to the current status of biodiversity and ecosystem services and trends and direct and indirect drivers of change (see chapters 3 and 4). It provided analysis of key policy instruments and governance options linked to specific scenarios identified in chapter 5. It assessed the links between relevant international agreements and initiatives and their mainstreaming across scales and sectors; analysed policy instruments and their application to the African context and considered the important role of indigenous and local knowledge in understanding nature's contributions to people. It highlighted the importance of creating an enabling environment for evidence-based decision-making, policy design and reviewed some of the existing policy support tools and methodologies.

Avoiding a perceived or real 'tragedy of the commons' requires effective institutional responses that can enable environmental resources to be managed so that they contribute towards human well-being without eroding natural capital. Many indigenous African systems are well placed to do this. Generally, the existence of weak institutional and human capacity undermine efforts for good governance of biodiversity and ecosystem services and nature's contributions to people, emphasising the need to prioritise environmental governance across scales in order to support the equitable use of resources and conservation.

Africans depend on biodiversity and ecosystem services for their livelihoods and well-being. Many of Africa's political, legal, institutional, economic, and social contexts present a major challenge for the sustainable management of natural resources. They are further manifested by different challenges faced by the population in Africa including devastating land degradation, population growth, invasive species and climate change.

Efforts have been taken by African countries to address issues of biodiversity conservation and ecosystem services preservation though signing and ratifying international agreements. This has resulted in African governments making high-level commitments to achieve their targets. However, despite their importance to local development, peace and security, issues of importance and relevance to indigenous and local people have not been incorporated into many of the agreements, while those that focused on indigenous issues, bringing little or no change to indigenous people's rights and livelihoods. The low level of domestication of these commitments has constrained the effective implementation and the achievement of agreed targets. Efforts towards poverty reduction and scaling up of resilience will benefit from harnessing synergies between agreements to deliver multiple benefits, which can help to balance patterns of access and allocation of ecosystem services. Moreover, an enabling environment that embraces Africa's diversity will help to ensure justice and fairness in access to the continent's diverse biodiversity and ecosystem services.

This chapter represents one of the few assessments of the status of policy options and institutions, especially with regards to scenarios, on African biodiversity and ecosystem services. There is generally a dearth of accessible peer-reviewed and/or grey literature to support a comprehensive assessment of policy and governance. It has therefore created challenges in exploring these issues and creates an opportunity for more frequent, comprehensive and extensive assessments. It also presents an opportunity to develop case studies and pilot projects that explore the different policy options and instruments specifically in the African context.

Due to science-policy implementation disconnects, most research findings have not yet been taken up and translated into action. More co-engaged efforts and co-production of knowledge between practice, policy, science and ILK systems, are needed to ensure a high level of awareness and the achievement of commitments, particularly among policy makers. For example, the use of the different concepts associated with biodiversity and ecosystem services, especially associated with the use of scenarios, may be confusing to policy makers and constrain their translation into policy options. It is important that Africa develop its own common understanding and interpretation of the different concepts to inform decisions and facilitate the design of appropriate policies. Finally, there is not enough collaboration or sharing of information and lessons learned among countries in the various regions in Africa. Effective cooperation and lesson-sharing are needed. It is equally important to ensure a platform for collaborative initiatives to ensure synergies. In this regard, the role of regional institutions cannot be overemphasised.

Africa has an ambitious development agenda that is critically tied to maintaining and sustainably harnessing its diverse natural systems and ecosystem services. In order to achieve this agenda, it is necessary for all stakeholders to make use of effective policies that minimise trade-offs and maximise synergies under uncertainty so as to achieve a desirable and prosperous future for Africa (Figure 6.7).

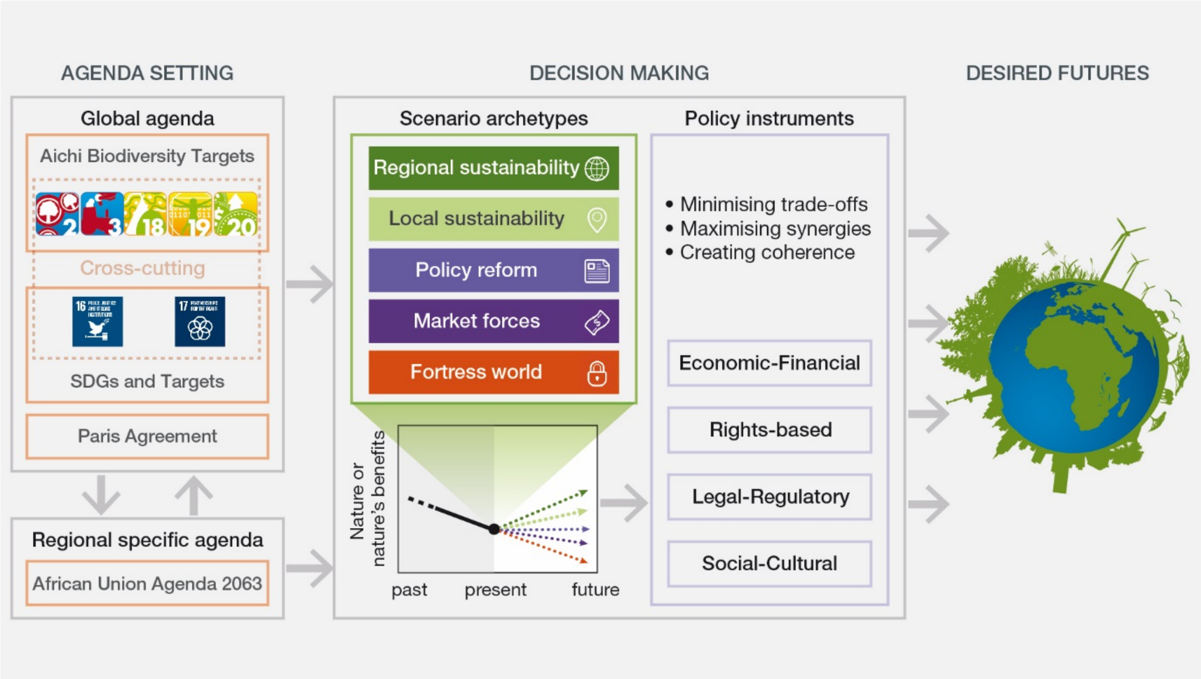

Figure 6.7: Summary of how effective global and regional agenda-setting combined with relevant decision-making tools can achieve desired future outcomes for Africa. Achieving a desirable and equitable future for Africa is based on an existing set of regional and global goals and targets. By using scenarios as a tool to think about how futures could play out, an enabling policy environment can be co-created to maximise synergies and coherence between actions and minimise trade-offs. This figure starts with a set of existing targets and objectives (Agenda 2063 of the African Union, the Sustainable Development Goals, the Aichi Biodiversity Targets and other globally agreed goals) that the majority of African nations have agreed to and that are necessary to achieve in order for the continent to reach a desirable future; some of these are cross-cutting because they aim to achieve institutional reform (e.g., Aichi Biodiversity Targets 2, 3, 18, 19 and 20 and Sustainable Development Goals 16 and 17) (See Table 5.7). Recognition of the cross-cutting institutional targets is critical as they focus on what needs to be done within and between institutions if a more desirable future is to be achieved. They not only map onto one cluster of targets e.g., around water or energy, but are necessary to achieve them all. To aid thinking about how to reach this agenda, there are a set of scenario archetypes that help us to conceptualise potential futures that could arise under different conditions and the trade-offs between each of these (See Box 5.2). None of these scenarios offer the desired future that we want; some of them get us closer to a desirable future than others, but the future is uncertain and a complex articulation of aspects of all these potential scenarios. In this light, scenarios are useful tools to help us think about the type of enabling environment necessary for achieving certain goals. Looking at the targets through the lens of the scenario archetypes enables decision-makers to make more informed decisions about what policy instruments could be employed (See Table 5.6), explicitly highlighting trade-offs and directing attention to specific synergies and coherence. The figure summarises how agenda-setting should be accompanied by effective decision-making that recognises future uncertainties in order to employ relevant policy instruments to achieve a desirable future.

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Appendix 6.1: Africa's progress in relation to the Aichi biodiversity targets.

Target 1: Awareness of biodiversity increased	African countries experience ongoing poaching activities, unsustainable management of land and water, reclamation of wetlands and other human activities that deplete natural resources and drive biodiversity loss. NGOs have developed ongoing activities to raise awareness of biodiversity and ecosystem service value in the region, helping decision-makers to weigh ecological, socio-cultural and economic values for development options, including conservation and sustainable use of natural resources. Indeed, according to the Green Africa Directory, there are more 50 African NGOs creating awareness on biodiversity and ecosystem services – see http://www.greenafricadirectory.org/listingtype/biodiversity-conservation-organisations/. The IUCN also leads an NGO Forum on Nature Conservation.
Target 2: Biodiversity values integrated	African countries are starting to use multiple natural capital accounting (NCA) tools to evaluate their biodiversity values and integrate them into national accounting, including ecosystem accounts, land and water accounts and location-specific tourism accounts. While challenges remain, these kinds of approaches help policymakers assess who 'wins' and 'loses' from ecosystem changes (WAVES, 2013) and provide complementary measures to GDP (Obst, 2015). In Zambia, the Reducing Emissions from Deforestation and Forest Degradation (REDD+) project has tried to put a value on the country's Forest reserves. Zambia's NBSAP also alludes to the values of biodiversity other than forest resources, including wetlands and wetlands resources, agro-ecosystems and agro-biodiversity resources as well as wildlife. The regulatory value of forest resources, for example in sediment retention by forests, is estimated at 274 million tons, generating a cost saving of $237 million per annum (Zambia's Second NBSAP-2 2015–2025). TEEB country studies in Liberia and Tanzania identify the ecosystem services vital to meeting countries' policy priorities and makes recommendations on how these services can be integrated into policies. The System of Environmental-Economic Accounting (SEEA) is also starting to be used as an international standard for producing national statistics on the environment and its relationship with the economy. The Wealth Accounting and the Evaluation of Ecosystem Services (WAVES) approach promotes sustainable development by ensuring that natural resources are mainstreamed in development planning and national economic accounts. WAVES helps countries to adopt and implement SEEA and has been applied in Botswana, Madagascar and Rwanda. Botswana aims to use natural capital as a diversification tool while Madagascar wants to tap into its biodiversity for sustainable growth. Rwanda wants to use NCA as a tool to realise sustainable development (WAVES, 2015). Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) have also been widely used since 1995 when African ministers of environment endorsed their use at the African Ministerial Conference on the Environment (AMCEN).
Target 3: Incentives reformed	African nations generally have fewer formal subsidies and incentive systems compared with other regions, yet are affected by subsidies and incentives elsewhere, making it hard for African countries to compete. REDD+ has emerged as an incentive opportunity for Africa. However, there is also a need to address subsidies that harm biodiversity, while also allowing Africa to develop greater food security and economic development.

Target 4: Sustainable consumption and production	Consumption of natural resources in Africa remains the lowest globally. However, Africa's consumption is growing, in line with human population increases, and this is putting increasing pressure on its ecosystems. Africa as a whole is predicted to soon show a bio-capacity deficit, where consumption footprints are greater than ecosystem capacity to provide goods, services and handle waste (AfDB-WWF, 2012). In response, an international process on achieving Sustainable Consumption and Production (SCP) has been launched. Africa has been active in this, hosting 162 of 1,015 SCP initiatives globally (SCP Clearing House, 2018). At the regional level, the African 10-Year Framework of Programmes (10-YFP) on Sustainable Consumption and Production launched by AMCEN, as part of the 2012 Marrakech Process on the 10-YFP, provides political impetus for the achievement of SCP in Africa. The Africa Roundtable on Sustainable Consumption and Production (ARSCP), a regional non-governmental not-for-profit organisation, has an overall objective to facilitate the development of national and regional capacities for SCP and promote effective implementation of the concepts and tools of SCP in African countries.
Target 5: Habitat loss halved or reduced	Despite positive efforts in many countries noting improvements in reducing habitat loss, mangrove and forest loss is continuing across Africa. Overall rates of loss indicate that several countries are moving away from reaching Target 5. Between 2001 and 2013 annual average tree cover loss for the African region was 0.2% and 2.57% of the total forest cover was lost during this period. In many places, these changes are being driven by rapid population growth and urbanisation (CBD Secretariat, 2014). Although loss continues in most countries, efforts are underway to reduce the rate of loss of forests and mangroves. Tanzania, Swaziland, Eritrea and Uganda proposed in their fifth national reports to increase and develop protected areas in order to rehabilitate forests in their countries. In other countries like Burkina Faso, there are efforts to promote dry season agriculture whilst in the Seychelles efforts are underway to promote a shift from forestry to ecotourism and fisheries. Other notable improvements in habitat loss can be noted in the Congo Basin in Central Africa where a study based on satellite images has revealed that deforestation rates have fallen by about a third since 2000, with fewer than 2,000 km^2 of rainforest lost every year between 2000 and 2010 (Mayaux *et al.*, 2013). This is due to the network of protected areas, forest gains on the margins of the Congo Basin forest, and the reduced expansion of commercial agriculture in the ten members of COMIFAC – Burundi, Cameroon, Chad, Congo, Democratic Republic of Congo, Central African Republic, Equatorial Guinea, Gabon, Rwanda, and São Tomé and Principe.
Target 6: Sustainable management of marine living resources	The achievement of this target is important in Africa as fishing is an important source of nutrition and income in the region. The main issues to be tackled are overfishing, bad fishing practices and pollution. According to the fifth national reports submitted to the CBD, most African countries are increasingly focusing their national policies on recovery plans for depleted fish stocks rather than on managing and reducing impacts of fishing practices. Some countries maintain subsidies of fishing fleets despite negative implications and the 1995 Fish Stocks Agreement (UN, 1995). There are initiatives by the FAO Fish Programme such as the *Strengthening the Knowledge Base for and*

	implementing an Ecosystem Approach to Marine Fisheries in Developing Countries. This programme supported Cote d'Ivoire to approve the Beach Seine fishery management plan in 2014, to contribute to the sustainable use of coastal fishery resources. Certification of fishery products such as that by the Marine Stewardship Council (MSC) has been used to promote sustainable fisheries in South Africa. There are nevertheless few fisheries in Africa that have been certified due to constraints that include mismatch between the reality of small-scale artisanal fisheries and the modern certification requirements. For most small-scale fisheries in developing countries, devolution of governance of fisheries to indigenous and local communities, shared governance and co-management have been found to produce successful outcomes. Examples of responsible stewardship and management of marine ecosystems include coastal communities through networks of several Locally-Managed Marine Areas (LMMAs) in Kenya, Tanzania and Senegal. Despite progress being made by African countries to achieve target 6, achieving sustainable fisheries remains a challenge. This is worsened by the presence of subsidised fleets in some regions of Africa, illegal fishing boats and slow progress with certification.
Target 7: Sustainable agriculture, aquaculture and forestry	There has been some successful effort to enhance the sustainability of forestry. However, the lack of data on sustainable agriculture and aquaculture has affected reporting of the extent and trends of these two sectors. The fifth national reports to the CBD suggest that in general, unsustainable agriculture, aquaculture and forestry are the main pressures on biodiversity whilst also recognising that these sectors are the major employers in Africa thus contributing to human well-being. In countries such as Burkina Faso, Ethiopia, Madagascar, Mozambique and Tanzania, over 75 % of people are employed in agriculture, while in Congo, Egypt, Morocco and Senegal, 30–45 % of employed people work in agriculture (FAO, 2013). Several countries are promoting community-based conservation agriculture (Swaziland) and organic farming (Egypt), and the setting up of guidelines for sustainable practices (South Africa). Similarly, in Burundi, Uganda, Sierra Leone and the Seychelles policies promoting sustainable forestry are in place and in Malawi, reforestation practices include national tree planting days. Use of forest concessions in the Congo Basin has helped to promote more sustainable forest management by providing logging companies with a long-term interest in managing the resource effectively. Further, the use of certification schemes, such as those promoted by the Forest Stewardship Council (FSC), is also helping to promote sustainable management (CBD Secretariat, 2014).
Target 8: Pollution reduced	To address challenges with nitrogen and phosphorous, 37 African countries adopted the *Kampala Statement for Action on Reactive Nitrogen in Africa and Globally* in 2013.The three issues addressed by the statement include (a) improving soil fertility status, nutrient use and supply; (b) acting on nutrient and fertiliser policy; and (c) reducing nitrogen's contribution to the degradation of water bodies and air pollution. Other sustainable land and water management measures being used by African countries include agroforestry in Malawi and Senegal; conservation agriculture in Zambia; rainwater harvesting in Burkina Faso; and integrated soil fertility management in West Africa. These practices have delivered positive results for soil quality and crop yields. Micro-dosing

	that involves combining conventional agriculture with improved seed varieties to reduce the amount of fertiliser used, has been used in Mali, Burkina Faso and Niger.
Target 9: Invasive alien species prevented and controlled	Efforts are underway to manage invasive alien species (IAS) in African countries. For example, Ethiopia, Malawi, Mali, Niger, Rwanda, South Africa and Uganda have programmes for the management of IAS. Other countries like Burkina Faso have established species lists. Egypt and Benin have allocated resources to study IAS and Sierra Leone, Somalia, Sudan and Swaziland have implemented programs to raise awareness of the effects of IAS.
Target 10: Pressures on vulnerable ecosystems reduced	Coral bleaching and damage to coral reefs has been well studied in East Africa and the Indian Ocean. Climate impacts on other vulnerable ecosystems, such as mountain peaks are also studied, for example, the retreat of ice on Mt Kilimanjaro. There is insufficient information on this target in the African region to assess progress.
Target 11: Protected areas increased and improved	Most African countries have already achieved, or are likely to achieve by 2020, elements of Target 11. Seychelles for example, surpassed the area suggested by Target 11 in 2011 when its government declared new protected areas in the archipelago, which resulted in over half of its total land area becoming protected areas (PAs) (Dogley, 2011). However, barriers still remain due to lack of institutional capacities, disparities in governance, social capital, and availability of ecological data. Twenty-two African countries and territories have over 17% of their land covered by PAs (including Reunion Island) and 4 have over 10% of their marine extent covered by PAs (including Mayotte) (UNEP-WCMC *et al.*, 2017). The unavailability of data makes it difficult to identify and develop protected areas because many countries cannot afford to undertake comprehensive and detailed research (Abdulla *et al.*, 2009). The focus in the expansion of reserves has been through the promotion of community-based forest and wildlife management, through engagement and management of local communities and through Indigenous and Community Conserved Areas (ICCAs) (http://www.iccaregistry.org). This kind of conservation management has provided a way for local people to benefit from conservation in countries like Namibia, whilst at the same time leading to increases in animal populations. Other undesirable outcomes, however, have included crop raiding by animals whose numbers have increased, and inadequate or insignificant benefits to the local communities.
Target 12: Extinction prevented	There is limited information to assess progress towards this target in Africa, although comprehensive data on extinction risk are now available through the IUCN Red List (see https://www.nature.com/articles/sdata20167). Similar to global trends, there is an indication that no progress is being made towards the prevention of the extinction of known threatened species. Populations of many species are still declining due to pressure from illegal trade in wildlife. CITES is working with a number of African countries in relation to wildlife crime. For example, *Operation Cobra II* led by Interpol, development of *National Ivory Action Plans*, production of *14 Urgent measures* in 2013, a monitoring programme called the *Monitoring of Illegal Killing of Elephants (MIKE)* and the *Wildlife Enforcement Monitoring System* (WEMS). At a regional level, there are conservation measures such as the *Regional Action Plan for the Conservation of*

	the Cross River Gorilla aimed at addressing the continued loss of gorillas by increasing the budget for law enforcement and deployment of eco-guards.
Target 13: Genetic diversity maintained	The genetic diversity of Africa's crops and livestock remains high. However, there have been some local declines but is still lower than in most regions. A number of actions have been undertaken in African countries to effectively capture and assess plant genetic resources. Molecular technologies have been adopted in Malawi, Namibia, Niger, Tanzania Zimbabwe Benin, Burkina Faso, Ethiopia and Kenya whilst conservation of indigenous, medicinal and traditional plant species has been promoted in Uganda and Nigeria. However, to effectively meet this target, more action needs to be undertaken. There is need to implement the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture and adopt existing and emerging information, computing, genomic technologies as possible responses to a conserve Africa's plant and animal genetic resources. Existing initiatives like Plant Breeding Capacity Building (GIPB), Biosciences Eastern and Central Africa (BECA) and the Southern African Development Community (SADC) Plant Genetic Resources Centre (SPGRC; http://www.spgrc.org.zm/) need to be supported to improve the institutional capacity of breeding systems, breeders and existing facilities.
Target 14: Ecosystem Services	African countries receive many benefits from biodiversity and in terms of ecosystem services to support livelihoods and well-being. However, the information base on the status and trends in ecosystem services in Africa is weak and considerable work is needed to assess how these services are changing in Africa and what actions are being taken to address negative changes.
Target 15: Ecosystems restored and resilience enhanced	Although there is not much data to measure the progress towards this target, the fifth National reports to the CBD have indicated the efforts that most African countries are taking to build ecosystem resilience. Most efforts have been through farmer-managed natural regeneration practices, mangrove restoration, and many other activities. Countries that have restoration projects including reforestation include Morocco, Niger, the Seychelles Algeria, Benin, Chad and Sudan. Others like Burundi and Côte D'Ivoire have initiated the process of determining carbon sequestration of forestry ecosystem through the integration of REDD+. AFR100, (the African Forest Landscape Restoration Initiative) was launched at UNFCCC COP21 and represents a regional effort aimed at restoring 100 million hectares of land in Africa by 2030. Currently, participating countries include Malawi Ethiopia, Kenya, Liberia, Madagascar Democratic Republic of Congo, Malawi, Rwanda, Togo and Uganda. Further action is however still needed for African countries to meet this target by 2020.
Target 16: Access to and sharing benefits from genetic resources	Twenty six countries have ratified the Nagoya Protocol and others are in the process of ratification. The COMIFAC project under UNEP helped ten countries in central Africa member of COMIFAC to ratify and implement the Nagoya Protocol. It aims for 70% of parliamentarians to be trained on the importance of ABS by 2016 and for at least 9 COMIFAC countries to have implementation strategies and action plans and execute activities by 2017. African countries nevertheless face several difficulties including lack of capacity in drafting legal and policy frameworks in order to integrate ABS into their national legislation.
Target 17: Biodiversity	Most of the post-2010 NBSAPs are developed and adopted at the national level, providing policy guidance on countries' actions on biodiversity and delivering action. Updating of NBSAPs not only helps Africa achieve Target 17, but will

Strategies and Action Plans	also aid countries to develop national poverty reduction strategies, national accounting, and other development plans. Updating and implementing NBSAPs fundamentally serves as an effective tool for mainstreaming biodiversity into broader national and local strategies, plans and policies.
Target 18: Traditional knowledge	Traditional knowledge is very important in Africa where many people remain closely connected to the land where they have lived for millennia and there are numerous distinct ethnic and language groups in the continent and its offshore islands. Language diversity in Africa started to decline after 1980 as people increasingly moved to large cities and the impacts of globalisation were starting to be felt. 338 languages in 34 African countries are now recorded as Vulnerable, Endangered or Extinct (Moseley, 2010), with Sudan having the highest number of threatened languages. Community-based natural resource management is one of the major ways to both conserve natural resources and promote traditional knowledge and is being increasingly utilised in Africa.
Target 19: Sharing information and knowledge	Knowledge, science and technology play a crucial role in assessing the status of biodiversity, identifying threats and setting priorities for conservation and sustainable use. In Africa, key information is still missing and data collection is limited. Between 2008 and 2014 the number of occurrences of African species records integrated into Global Biodiversity Information Facility (GBIF) increased from around 5 million to almost 20 million. However, many African species records are held in non-African institutions, and therefore the figures inaccurately reflect the data mobilisation capacity within the region.
Target 20: Mobilising resources from all sources	Serving as the major source of funding for developing countries to meet their obligations under the Convention on Biological Diversity (CBD), the major international financial mechanism assisting Africa for biodiversity conservation is the Global Environment Facility (GEF). GEF funds have been and are being utilised for 985 projects in Africa, of which 369 projects are based on biodiversity focal areas (GEF, 2014). The biodiversity projects are most commonly focused on mainstreaming biodiversity into laws, policies and regulations. African governments are pursuing other innovative ways of mobilising resources for biodiversity conservation.

Appendix 6.2: Policies and initiatives in Africa to support transboundary ecosystem governance.

Policies and initiatives	Description	Institution
Agenda 2063 for Africa	Aspiration 1 and 3 – Ensures positive socio economic transformation	NEPAD, Regional Economic Communities (RECs) and Member States
NEPAD Strategy 2014 – 2017 / NEPAD/AU/ AMCEN Initiative on environment	Contains regional priorities based on national issues. Promotion of regional development through integration at sub regional level.	NEPAD, RECs and Member States.
Transboundary River and Lake Basin Commissions	Protection of the resources of the transboundary water resources (biodiversity and ecosystems)	Lake Chad, Lake Victoria, Nile River, Niger River, Okavango, Limpopo, Zambezi, Senegal River etc.,
Transfrontier conservation areas (TFCA)	Protection of transboundary terrestrial resources (biodiversity and Ecosystems)	Maloti-Drakensberg Transfrontier Conservation and Development Area, Great Limpopo Transfrontier Conservation Area, Niger Delta, Ruwenzori, Mount Elgon. COMIFAC, Miombo Trans-frontier Commission.
Landscape Commissions	Conservation of National Resources. Reforestation	Algiers and Maputo convention Great Green Wall for the Sahara and the Sahel Initiative (GGWSSI)
Terrestrial Commissions	Conserving genetic Biodiversity through gene banks	SADC Plant Genetic Resources
Aquatic (Fresh and Marine)	COMESA fisheries and Aquaculture Strategy, Tuna Commission, Protection, Management and Development of Marine and Coastal Resources	COMESA South West Indian Nairobi and Abidjan Convention

Appendix 6.3: Examples of economic incentives and financial instruments and their application in Africa.

Instrument	Description	Illustrative applications in Africa
Payments for ecosystem services (PES)	PES schemes represent agreements in which beneficiaries of particular ecosystem services pay the providers of those services (Schomers *et al.*, 2013). Since their inception in the late 1990s, several PES schemes globally have influenced land-use change. Fewer studies have demonstrated impacts in increasing service provision, and fewer still the impacts on livelihoods. While significant risks and benefits of PES continue to be discussed, their capacity to link service providers to beneficiaries remains a powerful means of incentivising change through conservation.	Namirembe *et al.*, (2014) review 50 tree -based ecosystem service projects including co-investment, commodification, and compensation for carbon, water, habitat for biodiversity, and bundled services. Water Funds (e.g., the Nairobi Water Fund, and Tana Basin management) involve the private sector in incentivising land-use change upstream of urban drinking water sources. Tourism companies pay communities for the protection of wildlife (Tanzania, Kenya, Namibia, Zimbabwe (Campfire), Zambia (ADMADE). Revenue from wildlife accounts for up to 24% of GNP.
REDD+	REDD+ has been developed as an innovative way of mitigating climate change whilst at the same time generating considerable benefits for biodiversity and ecosystem services with the potential to extend the benefits to indigenous and local communities. Achievement of these multiple benefits requires close coordination between relevant stakeholders including local, international and national players. Activities aimed at achieving Afforestation and reforestation in the context of REDD+ therefore, if effectively implemented have potential to enhance ecological connectivity which is important in ecosystems adaptation (CBD Secretariat *et al.*, 2011)	Tanzania with the support of the government of Norway has piloted 9 REDD+ projects across Tanzania between 2009 and 2015. The pilots revealed the need for Tanzania to adapt participatory forest management to a REDD+ context which created funding and implementation opportunities for scaling up participatory forest management in various parts of the country. The pilots also showed that the REDD+ process contributed to strengthening forest management rights through community-based forest management. However, of the 9 pilot projects that were under the project, only 3 managed to produce (Project Design Documents) PDDs to support the sale of carbon credits. By 2015 however, none of these projects had managed to sell credits on the voluntary market. (Blomley *et al.*, 2016).
Overseas Development Assistance (ODA),	ODA has been a growing means of supporting biodiversity and ecosystem services. The Global Environment Facility (GEF) plays a key role in linking environmental quality and national development priorities through its role as the financial mechanism for the CBD, UNFCCC, and UNCCD amongst others.	The Volta Basin Authority with the financial support of the World Bank and the GEF has a $10 million project investing in large-scale “conservation and restoration of ecosystem function” including ten specific restoration activities that link environmental health with the water management priorities of the basin authority.
Emissions reductions trading	A market mechanism where emissions permits or allowances are distributed through trading. This is a global instrument introduced in the early 1990s to reduce national and trans-	Examples from Africa are scanty and not as successful as those assessed in Asia and Latin America. However, the mechanism has shown promising results

	boundary air pollution (GHGs) through trading of certified carbon credits.	in Ethiopia (afforestation and reforestation) and Kenya (soil carbon).
Carbon taxes and payments	Carbon taxes and payments are of interest particularly through REDD+ mechanisms and because they target a regulating ecosystem service.	For Africa in particular, financial incentives to conserve central African forests to offset the emissions from non-African countries will be reviewed. In the Congo Basin, the Earth's second-largest tropical forest extending over six countries, several large-scale REDD+ initiatives are implemented. The Forest Carbon Partnership Facility (FCPF), the REDD+ Partnership, the UN-REDD Programme, the Congo Basin Forest Fund (CBFF), and the Forest Investment Program (FIP) support the shared vision of offsetting the emissions from non-African countries by financially rewarding local stakeholders for enhanced forest management. While REDD was initially focused on reducing emissions from deforestation and forest degradation, REDD+ additionally aims to conserve and enhance forest carbon stocks and to promote sustainable forest management, which positively affects biodiversity conservation (Pavageau *et al.*, 2014).
Bans or permanent conservation easements	Permanent conservation easements guarantee that a tract of land will not be used or farmed. This usually involves an annotation in the property title or at the land registry office—national parks would be in this category. The negative counterpart of easements—bans—can ensure that products harmful to health or environmental quality such as pesticides are not used.	The ban on plastic bags in Rwanda immensely contributed towards reduced environmental pollution. Such measures may prove effective but may also bear actions of strong monitoring and regulatory measures, which might be costly to enforce.
Resource use fees	Resources use fees are conservation approaches whereby resource users pay royalty fees to holders of protected areas in return for a particular service or resource use within the protected areas. One example is trophy hunting. This is widely practised globally and individuals can be granted the right to hunt a certain wildlife species or to collect a certain wild plant material for economic, social and recreation purposes. The revenue collected is invested in infrastructure and management capacity building.	Community-based conservation programmes which establish an economic value for wildlife and provide incentives for sustainable use are an increasingly popular mechanism for returning to local communities the responsibility of managing their natural resources. Trophy hunting, in particular, has been identified as a rewarding form of wildlife use which may provide both community benefits and incentives for wildlife conservation. This has been implemented many southern African countries and studies suggest that it is not a sustainable form of wildlife protection. As has been observed in Tanzania, Botswana, Zambia, Zimbabwe and Namibia, the following

		conditions must be fulfilled to be successful: scientifically-determined wildlife population estimates, comprehensive quotas which are enforced, reputable and honest outfitters, transparent and accountable revenue collection and disbursement mechanisms, competent management and oversight of the industry, and fair distribution of proceeds at the local level.
Tradable permits	Unique to the African context is the sale of permits to harvest African wildlife. Permits allowing the hunting of biodiversity, particularly Africa's mega-fauna, many of which are threatened or endangered, are largely controversial but have provided hundreds of thousands of dollars to conservation efforts.	While controversial, the financing from permits can be used to support conservation efforts (e.g., the hunting permit for a single black rhino was valued at $350,000). Unique to the African context is the sale of permits to harvest African wildlife. Permits allowing the hunting of Africa's mega-fauna, many of which are threatened or endangered. The mechanism is largely controversial but has provided hundreds of thousands of dollars to conservation efforts. The premise is that an appropriately defined tradable-permit system can minimise the cost of reaching a predefined environmental target (Tietenberg, 2003). It is expected that in a perfectly competitive market, permits will flow towards their highest-valued use, and those that would receive lower value from using the permits would have an incentive to trade them to someone who would value them more. Overall, such trade benefits both parties. However, the potential of this system to protect the economic value of the resource, rather than the resource itself, has attracted criticism.
Offsetting schemes	The concept of "Biodiversity offset scheme" is designed to compensate for biodiversity loss or degradation caused by development projects in a particular area through tantamount restoration actions and habitat expansion elsewhere. The "offsets" can be traded and a project developer can compensate by buying "credits" from reserve managers or landowners who have managed and conserved biodiversity according to set standards. The approach has been increasingly integrated into government and lender policies (IUCN, 2014). Despite the potential to advance biodiversity	A good case example in Africa is Liberia, where a national biodiversity offset scheme has been prepared for the mining sector by the World Bank Group (World Bank, 2015). In an effort to conserve protected areas (particularly forest areas) facing competing land-uses such as commercial forestry (logging), mining and agriculture, a national biodiversity offset scheme is currently proposed for the mining sector and biodiversity conservation credits are to be established before any mining project is implemented. Projects will be required to purchase credits that are made available through the scheme.

	conservation, the scheme is not popularly implemented. There are concerns that it will undermine existing approaches and negatively encourages development against biodiversity conservation goals. The argument is there are hardly any success stories or empirical evidence and more uncertainty over the offset outcomes (IUCN, 2014). As governments and business seek to address the impacts of development projects on biodiversity, biodiversity offsets emerge as attractive option attracting increasing interest. They are largely based on the polluter pays principle. Biodiversity offsets are structured to compensate for critical damage to biodiversity through internalising the external costs of biodiversity loss and enforcing the payment of this cost in compensation for the loss (OECD, 2016).	However, the impact is yet to be seen in the years ahead. Another example is found in South Africa, where a biodiversity offsetting scheme has been exercised for the last six years (Jenner *et al.*, 2015). The most common objective adopted in offset programmes is to deliver "No Net Loss" to, for example, ecosystem function or a specific species (fauna or flora) etc. The AfDB Operational Safeguard 3 seeks to deliver a net benefit or no net loss on biodiversity and natural habitats. In this regard, biodiversity offsets are meant to be carried out as the final step of the mitigation pyramid (avoid, minimise, restore and offset)—to help meet a scheme's environmental objectives (AfDB, 2013). In South Africa, ecosystem mapping and classification has underlined the development and implementation of technical attributes of offsetting policy and has proved to be a crucial enabling factor in the design of offsets that are planned for biodiversity (Jenner *et al.*, 2015). Most African countries are undertaking significant infrastructural projects (roads, highways, dams, bridges, etc.) accompanied with ecosystem degradation significantly impacting the natural capital without real offsetting mechanisms. African biodiversity offsets are however attracting increasing interest as governments and the private sector seek to address biodiversity loss occurring through development activities. The African banking system could be better placed to play an active role in addressing ecosystem conservation. The African Development Bank is contributing to increased awareness amongst policy makers to closely align environmental impacts with those causing the damage and engaging the private sector, not only in financing conservation but also in implementing conservation solutions. This increases the possibility of governments allowing development in sensitive environments while assuring no net loss of ecosystem services and biodiversity and still gains the economic benefits of development. Types of biodiversity offsets considered include

		One-off offsets, In-lieu fees, and Bio-banking. Yet, markets in the continent remain underdeveloped for biodiversity mitigation and conservation. In Madagascar, Rio Tinto on its extraction at the Rio Tinto ilmenite mine is investing in biodiversity offsets at several forests (littoral and non-littoral) sites covering almost 6,000 ha of forest. If the project proceeds as planned, a net positive impact will be achieved thanks to biodiversity offset provisions.
Taxes and fiscal incentives	Environmental taxes are defined as: “Any compulsory, unrequited payment to general government levied on tax-bases deemed to be of particular environmental relevance” (OECD, 2017), where the tax bases “include energy products, motor vehicles, waste, measured or estimated emissions, natural resources etc.” Taxes are used to address market failures and externalities: impacts on ecosystems that are side-effects of production and consumption, and which do not enter into the calculations of those responsible for the processes. Where the effects are negative, externalities are costs. By levying a tax or charge on the activity giving rise to the effect, the external cost can be partially or wholly internalised.	Examples in Africa mainly relate to the forestry sector to promote sustainable forest management. The most common taxation takes the form of concession fees, royalty fees, stumpage fees, and export levies. Ghana applies some of these taxes as post-harvest fees (e.g., on processed wood products, sawn wood or plywood) and Cameroon applies concession fees on an annual basis on the area of forest land given out on concession.
Trade and foreign investments (green economy)	Movement towards a green economy can reduce the impact of economic growth on biodiversity and ecosystem services. However, this is distinct from approaches that finance or recognise the values of biodiversity and ecosystem services. A green economy approach reduces negative externalities on the environment, aiming to “rebuild natural capital (e.g., biodiversity and ecosystem services) as a critical economic asset and source of public benefits, especially for poor people whose livelihoods and security depend strongly on nature” (Huff, 2015), whereas ecosystem service-based approaches value the positive externalities of the environment on economic growth.	The Southern Agricultural Growth Corridor of Tanzania (SAGCOT) is a project managed by the office of the vice president of Tanzania. It aims to reconcile conservation, agricultural development and livelihood objectives, linking policy, private capital investments with conservation, economic growth and ecosystem services in a risk-sharing public-private partnership. The ecosystem service approach is applied in the context to ensure that agriculture and livelihood dependencies on ecosystem services are accounted for and acknowledged. Presently, WWF and IUCN are collaborating with the SAGCOT Centre to ensure a minimal biodiversity and ecosystem services impact (since there is controversy whether SAGCOT is about "green growth", due to e.g., impact on water availability).

Glossary of terms

A

Acceptance
Acceptance of the Platform’s outputs at a session of the Plenary signifies that the material has not been subjected to line-by-line discussion and agreement, but nevertheless presents a comprehensive and balanced view of the subject matter.

Accountability
Is an assurance that an individual or an organization will be evaluated on their performance or behaviour related to something for which they are responsible.

Adoption
Adoption of an IPBES report is a process of section-by-section (and not line-by-line) endorsement, as described in section 3.9, at a session of the Plenary.

Agro-ecological zones
Geographic areas with homogeneous sets of climatic parameters and natural resource characteristics, such as rainfall, solar radiation, soil types and soil qualities, which correspond to a level of agricultural potential.

Alliance for Zero Extinction sites
Refer to sites containing 95% or more of the remaining population of one or more species listed as endangered or critically endangered on the IUCN Red List of Threatened Species.

Approval
Approval of the Platform’s outputs signifies that the material has been subject to detailed, line-by-line discussion and agreement by consensus at a session of the Plenary.

Archetypes
In the context of scenarios, an over-arching scenario that embodies common characteristics of a number of more specific scenarios.

Arid ecosystems
Those in which water availability severely constrains ecological activity.

Aridification
A chronic reduction in soil moisture caused by an increase of mean annual temperature or a decrease in yearly precipitation.

B

Baseline
A minimum or starting point with which to compare other information (e.g., for comparisons between past and present or before and after an intervention).

Biodiversity
The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems.

Biodiversity hotspot
A generic term for an area high in such biodiversity attributes as species richness or endemism. It may also be used in assessments as a precise term applied to geographic areas defined according to two criteria (Myers *et al*., 2000): (i) containing at least 1,500 species of the world's 300,000 vascular plant species as endemics, and (ii) being under threat, in having lost 70% of its primary vegetation.

Biomass
The mass of non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms in a given area or volume.

Biome
Biomes are global-scale zones, generally defined by the type of plant life that they support in response to average rainfall and temperature patterns. For example, tundra, coral reefs or savannas.

Bushmeat
Meat for human consumption derived from wild animals.

Bushmeat hunting
Bushmeat (or wild meat) hunting is a form of hunting that entails the harvesting of wild animals for food and for non-food purposes, including for medicinal use.

C

Carbon footprint
A measure of the total amount of carbon dioxide emissions, including carbon dioxide equivalents, that is directly and indirectly caused by an activity or is accumulated over the life stages of a product.

Carbon-lock-in phase
Refers to the tendency for certain carbon-intensive technological systems to persist over time, 'locking out' lower-carbon alternatives, and owing to a combination of linked technical, economic, and institutional factors.

Climate variability
Is defined as variations in the mean state and other statistics of the climate on all temporal and spatial scale, beyond individual weather events.

Climate change
As defined in Article 1 of the UNFCCC, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods

Co-benefits
Refers to benefits of development plans or sectoral policies and measures.

Community-based natural resource management
Community-based natural resource management: an approach to natural resource management that involves the full participation of indigenous peoples' and local communities and resource users in decision-making activities, and the incorporation of local institutions, customary practices, and knowledge systems in management, regulatory, and enforcement processes. Under this approach, community-based monitoring and information systems are initiatives by indigenous peoples and local community organisations to monitor their community's well-being and the state of their territories and natural resources, applying a mix of traditional knowledge and innovative tools and approaches.

Corridor
A geographically defined area which allows species to move between landscapes, ecosystems and habitats, natural or modified, and ensures the maintenance of biodiversity and ecological and evolutionary processes.

Cross-scale Analysis
Cross-scale effects are the result of spatial and/or temporal processes interacting with other processes at another scale. These interactions create emergent effects that can be difficult to predict.

D

Deforestation
Human-induced conversion of forested land to non-forested land. Deforestation can be permanent, when this change is definitive, or temporary when this change is part of a cycle that includes natural or assisted regeneration.

Domestication of agreements' commitment
Refer to measures taken to give global agreement the power and the force of national legal systems and regulations to enable and facilitate their applicability in the national context while ensuring full compliance with international commitments.

Driver
In the context of IPBES, drivers of change are all the factors that, directly or indirectly, cause changes in nature, anthropogenic assets, nature's contributions to people and a good quality of life.

Direct drivers of change can be both natural and anthropogenic.

Direct drivers have direct physical (mechanical, chemical, noise, light etc.) and behaviour-affecting impacts on nature. They include, inter-alia, climate change, pollution, different types of land use change, invasive alien species and zoonoses, and exploitation.

Indirect drivers are drivers that operate diffusely by altering and influencing direct drivers as well as other indirect drivers. They do not impact nature directly. Rather, they do it by affecting the level, direction or rate of direct drivers. Interactions between indirect and direct drivers create different chains of relationship, attribution, and impacts, which may vary according to type, intensity, duration, and distance. These relationships can also lead to different types of spill-over effects. Global indirect drivers include economic, demographic, governance, technological and cultural ones, among others. Special attention is given, among indirect drivers, to the role of institutions (both formal and informal) and impacts of the patterns of production, supply and consumption on nature, nature's contributions to people and good quality of life.

E

Eco-labelling
"Is only one type of environmental labelling, and refers specifically to the provision of information to consumers about the relative environmental quality of a product".

Ecological footprint
A measure of the amount of biologically productive land and water required to support the demands of a population or productive activity. Ecological footprints can be calculated at any scale: for an activity, a person, a community, a city, a region, a nation or humanity as a whole.

Eco-region
A large area of land or water that contains a geographically distinct assemblage of natural communities that:

- Share a large majority of their species and ecological dynamics;
- Share similar environmental conditions, and;

Interact ecologically in ways that are critical for their long-term persistence (source: WWF). In contrast to biomes, an ecoregion is generally geographically specific, at a much finer scale. For example, the "East African Montane Forest" eco-region of Kenya (WWF eco-region classification) is a geographically specific and coherent example of the globally occurring "tropical and subtropical forest" biome.

Ecosystem
A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

Ecosystem function
The flow of energy and materials through the biotic and abiotic components of an ecosystem. It includes many processes such as biomass production, trophic transfer through plants and animals, nutrient cycling, water dynamics and heat transfer.

Ecosystem services
The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth. The concept ''ecosystem goods and services'' is synonymous with ecosystem services.

Ecotourism
Sustainable travel undertaken to access sites or regions of unique natural or ecological quality, promoting their conservation, low visitor impact, and socio-economic involvement of local populations.

Endangered species
A species at risk of extinction in the wild.

Endemism
The ecological state of a species being unique to a defined geographic location, such as an island, nation, country or other defined zone, or habitat type; organisms that are indigenous to a place are not endemic to it if they are also found elsewhere.

Energy security
Access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses.

Environmental assets
Naturally occurring living and non-living entities of the Earth, together comprising the bio-physical environment, that jointly deliver ecosystem services to the benefit of current and future generation.

Equity
Equity comprises three interlinked dimensions:

- **Distributive equity** highlights the need to consider not just the allocation of benefits, but also of costs and risks. Decisions about distribution can be justified on the basis of equality, social welfare, merit or need.
- **Procedural equity** encompasses fairness in political processes and participation in decision-making.
- **Contextual** equity recognises the fact that the playing field is never level, but that people's capabilities and their access to resources and power determine the extent to which they are able to utilise procedural equity to determine the best distributive outcome for themselves.

Exclusive Economic Zone
An Exclusive Economic Zone (EEZ) is a concept adopted at the Third United Nations Conference on the Law of the Sea (1982), whereby a coastal State assumes jurisdiction over the exploration and exploitation of marine resources in its adjacent section of the continental shelf, taken to be a band extending 200 miles from the shore. The Exclusive Economic Zone comprises an area which extends either from the coast, or in federal systems from the seaward boundaries of the constituent states (3 to 12 nautical miles, in most cases) to 200 nautical miles (370 kilometres) off the coast. Within this area, nations claim and exercise sovereign rights and exclusive fishery management authority over all fish and all Continental Shelf fishery resources.

F

Feedback
The modification or control of a process or system by its results or effects.

Food security
The World Food Summit of 1996 defined food security as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life".

Forest
A minimum area of land of 0.05–1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10–30 per cent with trees with the potential to reach a minimum height of 2–5 metres at maturity in situ. A forest may consist either of closed forest formations where trees of various stories and undergrowth cover a high proportion of the ground or open forest.

Forest degradation
A reduction in the capacity of a forest to produce ecosystem services such as carbon storage and wood products as a result of anthropogenic and environmental changes.

G

Good governance
The governance (as described above) which entails sound public sector management (efficiency, effectiveness and economy), accountability, exchange and free flow of information (transparency), and a legal framework for development (justice, respect for human rights and liberties).

In the development literature, the term 'good governance' is frequently used to denote a necessary pre-condition for creating an enabling environment for poverty reduction and sustainable human development.

Good quality of life
Within the context of the IPBES Conceptual Framework–the achievement of a fulfilled human life, a notion which may varies strongly across different societies and groups within societies. It is a context-dependent state of individuals and human groups, comprising aspects such as access to food, water, energy and livelihood security, and also health, good social relationships and equity, security, cultural identity, and freedom of choice and action. "Living in harmony with nature", "living-well in balance and harmony with Mother Earth" and "human well-being" are examples of different perspectives on a "Good quality of life".

Governance
The way the rules, norms and actions in a given organization are structured, sustained, and regulated. Governance options Refers to recommendation of options to be considered in

changing the government structure that would allow relevant stakeholders to ultimately determine their future.

Grassland
Type of ecosystem characterised by a more or less closed herbaceous (non-woody) vegetation layer, sometimes with a shrub layer, but–in contrast to savannas–without, or with very few, trees. Different types of grasslands are found under a broad range of climatic conditions.

H

Habitat
The place or type of site where an organism or population naturally occurs. Also used to mean the environmental attributes required by a particular species or its ecological niche.

Habitat degradation
A general term describing the set of processes by which habitat quality is reduced. Habitat degradation may occur through natural processes (e.g., drought, heat, cold) and through human activities (forestry, agriculture, urbanization).

Habitat fragmentation
A general term describing the set of processes by which habitat loss results in the division of continuous habitats into a greater number of smaller patches of lesser total and isolated from each other by a matrix of dissimilar habitats. Habitat fragmentation may occur through natural processes (e.g., forest and grassland fires, flooding) and through human activities (forestry, agriculture, urbanization).

Harmonization
The process of bringing together, and comparing, models or scenarios to make them compatible or consistent with one another.

I

Impact assessment
A formal, evidence-based procedure that assesses the economic, social, and environmental effects of public policy or of any human activity.

Important Bird & Biodiversity Areas
A Key Biodiversity Area identified using an internationally agreed set of criteria as being globally important for bird populations.

Indicators
A quantitative or qualitative factor or variable that provides a simple, measurable and quantifiable characteristic or attribute responding in a known and communicable way to a changing environmental condition, to a changing ecological process or function, or to a changing element of biodiversity.

Indigenous and local knowledge systems
Indigenous and local knowledge systems are social and ecological knowledge practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments. Such knowledge can provide information, methods, theory and practice for sustainable ecosystem management.

Indigenous people

- Are the holders of unique languages, knowledge systems and beliefs and possess invaluable knowledge of practices for the sustainable management of natural resources based on their traditional values, visions, needs and priorities.
- Are inheritors and practitioners of unique cultures and ways of relating to people and the environments.
- Indigenous people have retained social, cultural, economic and political characteristics that are distinct from those of the dominant societies in which they live.

Institutions
Encompasses all formal and informal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised, and how responsibilities are distributed.

Integrated Landscape management
Refers to long-term collaboration among different groups of land managers and stakeholders to achieve the multiple objectives required from the landscape.

Invasive alien species
Species whose introduction and/or spread by human action outside their natural distribution threatens biological diversity, food security, and human health and well-being. "Alien" refers to the species' having been introduced outside its natural distribution ("exotic", "non-native" and "non-indigenous" are synonyms for "alien"). "Invasive" means "tending to expand into and modify ecosystems to which it has been introduced". Thus, a species may be alien without being invasive, or, in the case of a species native to a region, it may increase and become invasive, without actually being an alien species.

IPBES Conceptual Framework
The Platform's conceptual framework has been designed to build shared understanding across disciplines, knowledge systems and stakeholders of the interplay between biodiversity and ecosystem drivers, and of the role they play in building a good quality of life through nature's contributions to people.

K

Key Biodiversity Areas
Sites contributing significantly to the global persistence of biodiversity. They represent the most important sites for biodiversity worldwide, and are identified nationally using globally standardised criteria and thresholds.

Knowledge systems
A body of propositions that are adhered to, whether formally or informally, and are routinely used to claim truth. They are organised structures and dynamic processes:

- generating and representing content, components, classes, or types of knowledge, that are
- domain-specific or characterised by domain-relevant features as defined by the user or consumer,
- reinforced by a set of logical relationships that connect the content of knowledge to its value (utility),
- enhanced by a set of iterative processes that enable the evolution, revision, adaptation, and advances, and,
- subject to criteria of relevance, reliability, and quality.

L

Land degradation
Refers to the many processes that drive the decline or loss in biodiversity, ecosystem functions or their benefits to people and includes the degradation of all terrestrial ecosystems.

Land Use
The human use of a specific area for a certain purpose (such as residential; agriculture; recreation; industrial, etc.). Influenced by, but not synonymous with, land cover. Land use change refers to a change in the use or management of land by humans, which may lead to a change in land cover.

Living in harmony with nature
Within the context of the IPBES Conceptual Framework–a perspective on good quality of life based on the interdependence that exists among human beings, other living species and elements of nature. It implies that we should live peacefully alongside all other organisms even though we may need to exploit other organisms to some degree.

M

Mainstreaming biodiversity
Mainstreaming, in the context of biodiversity, means integrating actions or policies related to biodiversity into broader development processes or policies such as those aimed at poverty reduction, or tackling climate change.

Market failures
Refers to situations whereby the market fails to give efficient allocation of resources, due to non-fulfilment of free and competitive market structure.

Market forces
Refer to economic factors affecting the price of, demand for, and availability of a commodity.

Millennium Ecosystem Assessment
The Millennium Ecosystem Assessment is a major assessment of the human

impact on the environment published in 2005.

Models
Qualitative or quantitative representations of key components of a system and of relationships between these components. Benchmarking (of models) is the process of systematically comparing sets of model predictions against measured data in order to evaluate model performance. Validation (of models) typically refers to checking model outputs for consistency with observations. However, since models cannot be validated in the formal sense of the term (i.e., proven to be true), some scientists prefer to use the words "benchmarking" or “evaluation".

A dynamic model is a model that describes changes through time of a specific process.

A process-based model (also known as “mechanistic model”) is a model in which relationships are described in terms of explicitly stated processes or mechanisms based on established scientific understanding, and model parameters therefore have clear ecological interpretation, defined beforehand.

Hybrid models are models that combine correlative and process-based modelling approaches.

A correlative model (also known as “statistical model”) is a model in which available empirical data are used to estimate values for parameters that do not have predefined ecological meaning, and for which processes are implicit rather than explicit.

Integrated assessment models are interdisciplinary models that aim to describe the complex relationships between environmental, social, and economic drivers that determine current and future state of the ecosystem and the effects of global change, in order to derive policy-relevant insights. One of the essential characteristics of integrated assessments is the simultaneous consideration of the multiple dimensions of environmental problems.

Mitigation
In the context of IPBES, an intervention to reduce negative or unsustainable uses of biodiversity and ecosystems.

Mother Earth
An expression used in a number of countries and regions to refer to the planet Earth and the entity that sustains all living things found in nature with which humans have an indivisible, interdependent physical and spiritual relationship (see "nature").

N

Native species
Indigenous species of animals or plants that naturally occur in a given region or ecosystem.

Nature's contributions to people
Nature's contributions to people (NCP) are all the contributions, both positive and negative, of living nature (i.e., diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to the quality of life for people. Beneficial contributions from nature include such things as food provision, water purification, flood control, and artistic inspiration, whereas detrimental contributions include disease transmission and predation that damages people or their assets. Many NCP may be perceived as benefits or detriments depending on the cultural, temporal or spatial context.

O

Overexploitation
Means harvesting species from the wild at rates faster than natural populations can recover. Includes overfishing, and overgrazing.

P

Polycentric governance system
Refers the organisation of small-, medium-, and large-scale democratic units that each may exercise considerable independence to make and enforce rules within a circumscribed scope of authority for a specified geographical area. Some units may be general-purpose governments whereas others may be highly specialized.

Protected area
A protected area is a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.

Provisioning services
The products people obtain from ecosystems; may include food, freshwater, timber, fibres, medicinal plants.

R

Ramsar sites
A Ramsar site is a wetland site designated of international importance especially as Waterfowl Habitat under the Ramsar Convention, an intergovernmental environment treaty established in 1975 by UNESCO, coming into force in 1975.

Ramsar site refers to a wetland of international significance in terms of ecology, botany, zoology, limnology or hydrology. Such site meets at least one of the criteria of Identifying Wetlands of International Importance set by Ramsar Convention and is designated by appropriate national authority to be added to Ramsar list.

Resilience
The level of disturbance that an ecosystem or society can undergo without crossing a threshold to a situation with different structure or outputs. Resilience depends on factors such as ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics.

Restoration
Any intentional activities that initiates or accelerates the recovery of an ecosystem from a degraded state.

Richness
The number of biological entities (species, genotypes, etc.) within a given sample. Sometimes used as synonym of species diversity.

S

Savanna
Ecosystem characterised by a continuous layer of herbaceous plants, mostly grasses, and a discontinuous upper layer of trees that may vary in density.

Scenario
Representations of possible futures for one or more components of a system, particularly for drivers of change in nature and nature’s benefits, including alternative policy or management options.

Exploratory scenarios (also known as “explorative scenarios” or “descriptive scenarios”) are scenarios that examine a range of plausible futures, based on potential trajectories of drivers–either indirect (e.g., socio-political, economic and technological factors) or direct (e.g., habitat conversion, climate change).

Target-seeking scenarios (also known as “goal-seeking scenarios” or “normative scenarios”) are scenarios that start with the definition of a clear objective, or a set of objectives, specified either in terms of achievable targets, or as an objective function to be optimized, and then identify different pathways to achieving this outcome (e.g., through backcasting).

Intervention scenarios are scenarios that evaluate alternative policy or management options–either through target seeking (also known as “goal seeking” or “normative scenario analysis”) or through policy screening (also known as “ex-ante assessment”). Policy-evaluation scenarios are scenarios, including counterfactual scenarios, used in ex-post assessments of the gap between policy objectives and actual policy results, as part of the policy-review phase of the policy cycle. Policy-screening scenarios are scenarios used in ex-ante assessments, to forecast the effects of alternative policy or management options (interventions) on environmental outcomes.

Socioecological system
An ecosystem, the management of this ecosystem by actors and organizations, and the rules, social norms, and conventions underlying this management.

Social responsibility
Refers to "transparent social practices that are based on

ethical values, compliance with legal requirements, and respect for people, communities, and the environment".

Stakeholders
Any individuals, groups or organizations who affect, or could be affected (whether positively or negatively) by a particular issue and its associated policies, decisions and action.

Summary for policymakers
Is a component of any report, providing a policy-relevant but not policy prescriptive summary of that report.

Supporting material
Consists of four categories:

- Intercultural and inter-scientific dialogue reports that are based on the material generated at the eco-regional level by discussions between members of academic, indigenous and social organizations and that take into account the different approaches, visions and knowledge systems that exist as well as the various views and approaches to sustainable development;
- Workshop proceedings and materials that are either commissioned or supported by the Platform;
- Software or databases that facilitate the use of the Platform's reports;
- Guidance materials (guidance notes and guidance documents) that assist in the preparation of comprehensive and scientifically sound Platform reports and technical papers.

Sustainability
A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs.

Sustainable use (of biodiversity and its components)
The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

Sustainable Development Goals (SDGs)
A set of goals adopted by the United Nations in 2015 to end poverty, protect the planet, and ensure prosperity for all, as part of the 2030 Agenda for Sustainable Development.

T

Tele-coupling
Tele-coupling refers to socioeconomic and environmental interactions over distances. It involves distant exchanges of information, energy and matter (e.g., people, goods, products, capital) at multiple spatial, temporal and organizational scales.

Threatened species
In the IUCN Red List terminology, a threatened species is any species listed in the Red List categories Critically Endangered, Endangered, or Vulnerable.

Tipping point
A set of conditions of an ecological or social system where further perturbation will cause rapid change and prevent the system from returning to its former state.

Trade-off
A trade-off is a situation where an improvement in the status of one aspect of the environment or of human well-being is necessarily associated with a decline in or loss of a different aspect. Trade-offs characterise most complex systems, and are important to consider when making decisions that aim to improve environmental and/or socio-economic outcomes. Trade-offs are distinct from synergies (the latter are also referred to as "win-win" scenarios): synergies arise when the enhancement of one desirable outcome leads to enhancement of another.

Transformation
In an organizational context, it refers to profound and radical change that orients an organization in a new direction and takes it to an entirely different level of effectiveness.

U

Uncertainty
Any situation in which the current state of knowledge is such that:

- the order or nature of things is unknown,
- the consequences, extent, or magnitude of circumstances, conditions, or events is unpredictable, and
- credible probabilities to possible outcomes cannot be assigned.

Uncertainty can result from lack of information or from disagreement about what is known or even knowable. Uncertainty can be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgment of a team of experts).

Units of analysis
The IPBES Units of Analysis result from subdividing the Earth's surface into units solely for the purposes of analysis. The following have been identified:

IPBES units of analysis (terrestrial):
- Tropical and subtropical dry and humid forests
- Temperate and boreal forests and woodlands
- Mediterranean forests, woodlands and scrub
- Tundra and High Mountain habitats
- Tropical and subtropical savannas and grasslands
- Temperate Grasslands
- Deserts and xeric shrublands
- Wetlands–peatlands, mires, bogs
- Urban/Semi-urban
- Cultivated areas (incl. cropping, intensive livestock farming etc.)

IPBES units of analysis (aquatic, including both marine and freshwater units):
- Cryosphere
- Aquaculture areas
- Inland surface waters and water bodies/freshwater
- Shelf ecosystems (neritic and intertidal/littoral zone)
- Open ocean pelagic systems (euphotic zone)
- Deep-Sea
- Coastal areas intensively used for multiple purposes by humans

These IPBES terrestrial and aquatic units of analysis serve as a framework for comparison within and across assessments and represent a pragmatic solution, which may evolve as the work of IPBES develops. The IPBES terrestrial and aquatic units of analysis serve the purposes of IPBES, and are not intended to be prescriptive for other purposes.

V

Values
Value systems: Set of values according to which people, societies and organizations regulate their behaviour. Value systems can be identified in both individuals and social groups (Pascual *et al*., 2017).

Value (as principle): A value can be a principle or core belief underpinning rules and moral judgments. Values as principles vary from one culture to another and also between individuals and groups (IPBES/4/INF/13).

Value (as preference): A value can be the preference someone has for something or for a particular state of the world. Preference involves the act of making comparisons, either explicitly or implicitly. Preference refers to the importance attributed to one entity relative to another one (IPBES/4/INF/13).

Value (as importance): A value can be the importance of something for itself or for others, now or in the future, close by or at a distance. This importance can be considered in three broad classes:
- The importance that something has subjectively, and may be based on experience.
- The importance that something has in meeting objective needs.
- The intrinsic value of something (IPBES/4/INF/13).

Value (as measure): A value can be a measure. In the biophysical sciences, any quantified measure can be seen as a value (IPBES/4/INF/13).

Non-anthropocentric value: A non-anthropocentric value is a value centred on something other than human beings. These values can be non-instrumental or instrumental to non-human ends (IPBES/4/INF/13).

Intrinsic value: This concept refers to inherent value, that is the value something has independent of any human experience and evaluation. Such a value is viewed as an inherent property of the entity and not ascribed or generated by external valuing agents (Pascual *et al*., 2017).

Anthropocentric value: The value that something has for human beings and human purposes (Pascual *et al*., 2017).

Instrumental value: The value attributed to something as a means to achieving a particular end (Pascual *et al*., 2017).

Non-instrumental value: The value attributed to something as an end in itself, regardless of its utility for other ends.

Relational value: The values that contribute to desirable relationships, such as those among people or societies, and between people and nature, as in “Living in harmony with nature” (IPBES/4/INF/13).

Integrated valuation: The process of collecting, synthesizing, and communicating knowledge about the ways in which people ascribe importance and meaning of NCP to humans, to facilitate deliberation and agreement for decision making and planning (Pascual *et al*., 2017).

W

Water security
The capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.

Water stress
Water stress occurs in an organism when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use.

Well-being
A perspective on a good life that comprises access to basic resources, freedom and choice, health and physical well-being, good social relationships, security, peace of mind and spiritual experience. Well-being is achieved when individuals and communities can act meaningfully to pursue their goals and can enjoy a good quality of life. The concept of human well-being is used in many western societies and its variants, together with living in harmony with nature, and living well in balance and harmony with Mother Earth. All these are different perspectives on a good quality of life.

Z

Zoonotic diseases
Zoonotic disease or zoonoses are directly transmitted from animals to humans via various routes of transmission (e.g., air-influenza; bites and saliva-rabies)

Glossary References

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Accronyms

10-YFP	African African 10-Year Framework of Programmes
ABS	Access and Benefit-Sharing
ABTs	Aichi Biodiversity Targets
ACBF	African Capacity Building Foundation
ADMADE	Administrative Management Design for Game Management Areas
AfDB	African Development Bank
AFR100	African Forest Landscape Restoration Initiative
AMCEN	African Ministerial Conference on the Environment
AMD	African Marine Domain
APP	Africa Progress Panel
ARIPO	African Regional Intellectual Property Organization
ARSCP	Africa Roundtable on Sustainable Consumption and Production
AU	African Union
AUC	African Union Commission
AUPFP	African Union Policy Framework for Pastoralism
BECA	Biosciences Eastern and Central Africa
BES	Biodiversity and Ecosystem Services
CAMPFIRE	Communal Areas Management Programme for Indigenous Resources
CAPMAS	Central Agency for Public Mobilization and Statistics
CARPE	Central Africa Regional Program for the Environment
CBD	Convention on Biological Diversity
CBFF	Congo Basin Forest Fund
CBNRM	Community-Based Natural Resource Management
CCLME	Canary Current Large Marine Ecosystem
CDKN	Climate and Development Knowledge Network
CEPF	Critical Ecosystem Partnership Fund
CIFOR	Centre for International Forestry Research
CITES	Convention on International Trade in Endangered Species
CMS	Convention on Conservation of Migratory Species of Wild Animals
COMIFAC	Commission des Forêts d'Afrique Centrale / Central African Forest Commission
DAFF	Department Of Agriculture, Forestry and Fisheries
DDT	Dichlorodiphenyltrichloroethane
DPSIR	Drivers, Pressures, State, Impact, Response
DRC	Democratic Republic of the Congo

EAC	East Africa Community
EAMCEF	Eastern Arc Mountains Conservation Endowment Fund
EBAFOSA	Ecosystem-Based Adaptation for Food Security in Africa Assembly
EIA	Environmental Impact Assessment
ELD	Economics of Land Degradation
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FAO-ITTO	Food and Agriculture Organization-International Tropical Timber Organization
FCPF	Forest Carbon Partnership Facility
FIP	Forest Investment Programme
FRB	Fondation pour la Recherche sur la Biodiversité
GCLME	Guinea Current Large Marine Ecosystem
GCM	Global Circulation Model
GDP	Gross Domestic Product
GDSA	Gaborone Declaration for Sustainability in Africa
GEF	Global Environment Facility
GEO-6 (or 2–5)	Global Environment Outlook 6
GGWSSI	Great Green Wall for the Sahara and the Sahel Initiative
GHG	Greenhouse Gas
GIPB	Global Partnership Initiative for Plant Breeding Capacity Building
GIS	Geographic Information System
GISP	Global Invasive Species Programme
GSG	Global Scenarios Group
HADCM	Hadley Centre Coupled Model
HDRO	Human Development Reports Office
IAEA	International Atomic Energy Agency
IAS	Invasive Alien Species
ICCA	Indigenous and Community Conserved Area
ICDP	Integrated Conservation Development Project
ICSU	International Council of Scientific Unions
ICT	Information and Communications Technologies
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IIED	International Institute for Environment and Development
ILK	Indigenous and Local Knowledge
ILKP	Indigenous and Local Knowledge and Practices
ILM	Integrated Landscape Management

InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
IOC	Indian Ocean Commission
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPCC SRES	Intergovernmental Panel on Climate Change Special Report on Emissions
ISO	International Organization for Standardization
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
IUCN	International Union for Conservation of Nature
LAC	Land Administration Committee (of Ethiopia)
LEGEND	Land: Enhancing Governance for Economic Development
LHDA	Lesotho Highlands Development Authority
LME	Large Marine Ecosystem
LMMA	Locally-Managed Marine Areas
LPFN	Landscape for People, Food and Nature
MA	Millennium Ecosystem Assessment
MEA	Multilateral Environmental Agreements
MEP	Multidisciplinary Expert Panel
MESH	Mapping Ecosystem Services to Human Well-being
MIKE	Monitoring of Illegal Killing of Elephants
MNRT	Ministry of Natural Resources and Tourism in Tanzania
MPI	Multidimensional Poverty Index
MSC	Marine Stewardship Council
NBSAP	National Biodiversity Strategy and Action Plan
NCP	Nature’s Contributions to People
NEMA	National Environment Management Authority (of Uganda)
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organisation
NP/ABS	Nagoya Protocol on Access and Benefit-Sharing
NPP	Net Primary Production
NQA	National Quality Assurance (ISO Certification)
NRC	Natural Resources Canada
NTFPs	Non-Timber Forest Products
OECD	Organisation for Economic Cooperation and Development
OSS	L'Observatoire du Sahara et du Sahel / Sahara and Sahel Observatory
PATTEC	Pan African Tsetse and Trypanosomiasis Eradication Campaign
PDD	Project Design Document
PERSGA/GEF	The Regional Organization for the Conservation of the Environment of the Red

	Sea & Gulf of Aden/Global Environment Facility
PES	Payments for Ecosystem Services
PPP	Public Private Partnership
RCP	Representative Concentration Pathway
RECs	Regional Economic Communities
REDD+	Reducing Emissions from Deforestation and Forest Degradation + the sustainable management of forests, and the conservation and enhancement of forest carbon stocks
RSA	Republic of South Africa
SADC	Southern African Development Community
SAGCOT	Southern Agricultural Growth Corridor of Tanzania
SANBI	South African National Biodiversity Institute
SCP	Sustainable Consumption and Production
SDGs	Sustainable Development Goals
SEA	Strategic Environmental Assessment
SEEA	System of Environmental-Economic Accounting
SIDS	Small Island Developing States
SPM	Summary for Policymakers
TEEB	The Economics of Ecosystems and Biodiversity
TFCA	Transfrontier Conservation Area
UK	United Kingdom
UN	United Nations
UN HABITAT	United Nations Human Settlements Programme
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNDRIP	United Nations Declaration on the Rights of Indigenous People
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UNEP-WCMC	United Nations Environment Programme-World Conservation Monitoring Centre
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNESCO-IHE	United Nations Educational, Scientific and Cultural Organisation-Institute for Water Education
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Fund
UNICEF	United Nations Children’s Fund
UNISDR	United Nations International Strategy for Disaster Reduction

UNODC	United Nations Office On Drugs And Crime
UNWTO	United Nations World Tourism Organization.
USA	United States of America
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VGGT	Voluntary Guidelines on the Responsible Governance of Tenure
WaterGAP	Water: A Global Assessment and Prognosis
WAVES	Wealth Accounting for Valuation of Ecosystem Services
WCPA	World Commission on Protected Areas
WEC	World Energy Council
WEMS	Wildlife Enforcement Monitoring System
WHC	World Heritage Convention
WHO	World Health Organization
WMO	World Meteorological Organization
WOAH	World Organisation for Animal Health
WWAP	United Nations World Water Assessment Programme
WWF	World Wide Fund For Nature