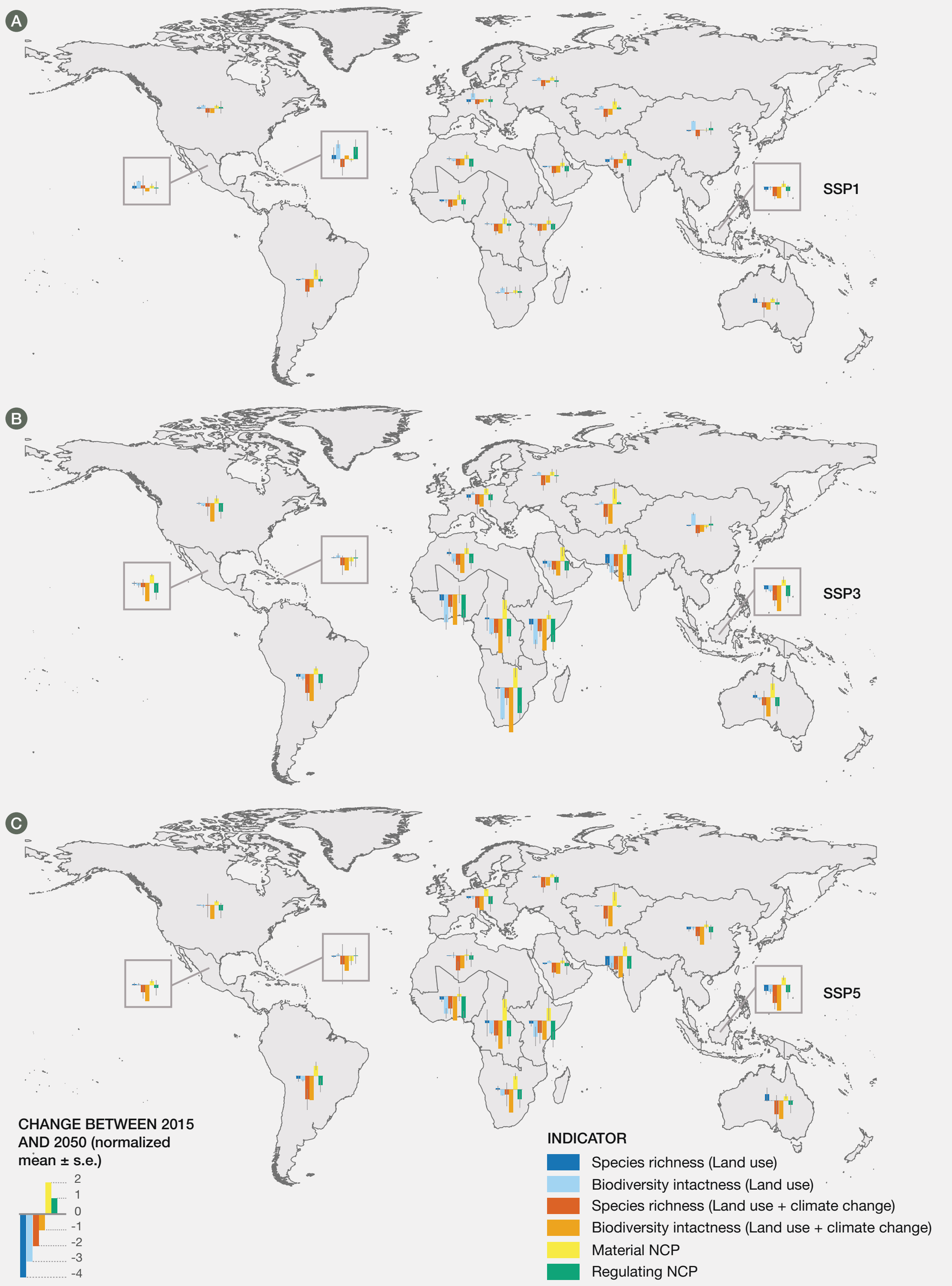


Figure 4 2 15 **Projected changes in biodiversity and nature's contributions to people for the IPBES subregions for a 'global sustainability' scenario (SSP1), a 'regional competition' scenario (SSP3) and an 'economic optimism' scenario (SSP5) between 2015 and 2050.**

To allow for direct comparison across scenarios and subregions, absolute mean values of change have been standardized by dividing the individual value of a metric by the standard deviation of all the values of that metric for all subregions in all scenarios (see Appendix A4.2.3 for details).

The projected impacts of climate change on biodiversity are much greater than land-use change in this study, but there is large uncertainty in this result. There is considerable debate concerning the relative sensitivity of species response to land use vs. climate change (Bellard *et al.*, 2012; IPBES, 2018g, 2018j, 2018h, 2018i; Pereira *et al.*, 2010). This multi-model study suggests that climate change will dominate biodiversity responses as early as 2050 for all biodiversity metrics, but this outcome needs to be treated with considerable caution for several reasons including i) very high uncertainty in models of climate change impacts on biodiversity (see error bars in **Figure 4.2.14**, and Settele *et al.*, 2014 for a discussion of uncertainties), ii) there are small differences in projected land-use change across the three scenarios compared to the range in a wider set of plausible futures (Alexander *et al.*, 2017c; Pereira *et al.*, 2010; but see Popp *et al.*, 2010) showing that the three scenarios used here cover nearly the full spectrum of land-use change in the SSP scenarios set), iii) issues related to defining land-use classes and using a very small set of land-use classes and iv) optimistic assumptions about food production increases that contribute to relatively small land-use changes while neglecting impacts of agricultural intensification (see drivers section 4.1.4).

There are high levels of uncertainty associated with these projected impacts, as is the case in other studies. There are a number of general and specific limitations to the BES-SIM results. Generally, the models used to foresee future land-use change, as well as the models of climate change impacts on biodiversity and most ecosystem services have not been well evaluated with data (Alexander *et al.*, 2017c; Ferrier *et al.*, 2016; Settele *et al.*, 2014; van Vliet *et al.*, 2016a). In addition, all models have intrinsic limitations due to underlying hypotheses and simplifications (Ferrier *et al.*, 2016). For example, none of the models of species response to climate change used in the BES-SIM study explicitly accounts for the capacity of organisms to adapt to climate change, or for species-interactions (Kim *et al.*, 2018). Model outputs have been grouped into categories of metrics, but these groupings mask important differences in interpretation of metrics from the various models (Kim *et al.*, 2018). For example, interpretation of ecosystem service indicators is challenging because they are expressed in very different units. Nevertheless, besides constituting the first comparison of a broad range of models using a common set of climate and land-use scenarios, one of the benefits of the BES-SIM study was to help to quantify some of the components of uncertainty, and while the difference between models was large for all metrics **(Figure 4.2.14)**, the overall qualitative trends were similar.

Likewise, future land-cover change scenarios and different spatial patterns that have been projected for each of the four RCPs will affect buffer zones that surround existing protected areas (Beaumont & Duursma, 2012). In most biomes modelled in this study (Beaumont & Duursma, 2012), previously unused land in buffer areas is projected to decline considerably by 2050 and more so by 2100. The projected decline in local species richness might be similar for low and high emissions scenarios, if the low emissions scenario necessitates large conversion of primary vegetation, for instance for bioenergy crops (RCP2.6; Newbold *et al.*, 2015). In contrast, a scenario focusing on globally sustainable resource use, consumption change, and associated habitat restoration indicated that both extinction risks and species losses would strongly be reduced over the next decades (Visconti *et al.*, 2016). Likewise, scenarios of increasing carbon prices as incentives to increase return from maintaining forested areas under a REDD mechanism drastically reduced local extinctions, especially in regions with high species richness (Strassburg *et al.*, 2012).

Estimates of impacts of land-use change on ecosystems and biodiversity need to consider urban areas and landscapes. Over the coming decades, some ecoregions and biodiversity hotspots will lose remaining undeveloped area through urban development, with localised large pressures on rare species and protected areas (Güneralp & Seto, 2013; McDonald *et al.*, 2008; Seto *et al.*, 2012). Nonetheless, a number of indicators of bird biodiversity differed little between urbanised and non-urbanised environments (Pautasso *et al.*, 2011). In Australia, some cities support a relatively larger number of threatened plant and animal species compared to non-urban landscapes (Ives *et al.*, 2016). With ongoing and future projected urbanisation of human societies, impacts of cities, larger urban areas and land transportation networks clearly must be included in scenarios of future biodiversity at different spatial scales.

Projected anthropogenic land-cover change and intensification of agriculture and pastures will enhance emissions of greenhouse gases. Future emissions of N_2O from terrestrial ecosystems in response to deposition and fertiliser use and climate change are projected to be enhanced by ca. 20% to threefold by the middle of the 21st century across a range of RCP (2.6, 8.5) and SRES scenarios (A1, B1, A2, B2) (Bodirsky *et al.*, 2012; Kanter *et al.*, 2016; Stocker *et al.*, 2014). Other gaseous forms of N losses (NOx and NH3) and their atmospheric reactions affect secondary organic aerosols, the lifetime of methane, or formation of tropospheric ozone (Bodirsky *et al.*, 2012; Butterbach-Bahl *et al.*, 2011; Kanter *et al.*, 2016; Lassaletta *et al.*, 2016; Zaehle *et al.*, 2015), and pollute waterways (section 4.2.3). On the other hand, land management practices in cropland, pastures and managed forests have been estimated to potentially contribute to emissions reductions by 1.5-4.8 Gt CO_2eq a-1 (Griscom *et al.*, 2017; Smith *et al.*, 2014a) achievable over few decades at carbon prices up to 100 $ US, without detrimental side effects on productivity, water use or biodiversity. This greenhouse emissions reduction potential might be tripled if food demand-side measures are also taken.

4.2.4.3 Future global ecosystem functioning and biodiversity in strong climate change mitigation scenarios

Land use is becoming increasingly central in future scenarios that target strong climate change mitigation (Popp *et al.*, 2017). Avoided deforestation (in conjunction with afforestation and reforestation, AR) is seen as one possible option (Angelsen, 2010; Chazdon *et al.*, 2016; Cunningham *et al.*, 2015; Smith & Torn, 2013; Strassburg *et al.*, 2012), which is also low-cost (Griscom *et al.*, 2017; Humpenoder *et al.*, 2014). Co-benefits of avoided deforestation for biodiversity (see **Figure 4.2.2**, Table A4.2.1 in Appendix 4.2) and local communities can be large, whereas the environmental impacts of large-scale afforestation and reforestation depend to a large degree on prior vegetation cover and the tree species planted for reforestation. Under the Paris COP21 climate agreement, forest-based climate mitigation targets feature prominently in several countries' Nationally Determined Contributions (Grassi *et al.*, 2017). Likewise, bioenergy in combination with carbon capture and storage (BECCS) has been put forward as a major land-based climate change mitigation approach in many scenarios that achieve a target of 2°C warming or below (Fuss *et al.*, 2016; see IPCC, 2018, Chapter 4.3.7; Popp *et al.*, 2014; Smith *et al.*, 2016). In Integrated Assessment Models (IAMs), the global cumulative C-uptake potential has been estimated to be ca. 55-190 GtC for avoided deforestation and AR at the end of the 21st century, and between ca. 125-250 GtC for BECCS (Humpenoder *et al.*, 2014; Tavoni & Socolow, 2013). Annual carbon uptake in 2050 for BECCS (1-2.2 GtC a^{-1}) and AR (0.1-1 GtC a^{-1}) is equivalent to up to one third to three quarters of today`s land carbon sink (IPCC, 2018, Chapter 4.3.7; Le Quéré *et al.*, 2018). In absence of carbon capture and storage, IAM projections may indicate even higher use of bioenergy (although it remains unclear how the required land area could be made available in an overall environmentally sustainable manner), unless the IAM scenarios are based on reduced energy consumptions and/or availability of cheap renewable energy, which reduces the need for land-related climate change mitigation (IPCC, 2018, Chapter 2.3). Analyses of ecosystem carbon uptake with dynamic global vegetation models (Fisher *et al.*, 2010) have arrived at consistently lower numbers than land-use models in IAMs when confronted with similar land-use change projections (Krause *et al.*, 2018). The reasons for the discrepancies in carbon uptake potential calculated with IAMs and DGVMs are not yet fully resolved. Indirect land-use changes complicate projections further. For instance, Popp *et al.* (2014) argued that stringent forest conservation policies could well lead to a spill-over effect such that land transformation for agriculture is shifted to other carbon-rich and biodiversity-rich ecosystems such as savannahs or temperate grasslands. Stringent climate change mitigation affects ecosystem productivity through bounded temperatures (and precipitation), but also via lower CO_2 in the atmosphere. Stabilizing or reducing the atmospheric concentration of CO_2 is expected to stabilize or reduce the fertilization effect of photosynthesis and is likely to also stabilize or reduce productivity compared to present-day levels (Jones *et al.*, 2016; Pugh *et al.*, 2016b).

Growth of bioenergy in simulation studies is in some cases restricted to marginal lands to avoid competing with food production, with the implicit assumption that these marginal lands would also be diversity-poor, which is not necessarily the case (Plieninger & Gaertner, 2011). The published studies mostly lack a clear definition and do not quantify the criteria used for classifying marginal or degraded land (de Jong *et al.*, 2011). Schueler *et al.* (2016) mapped the sustainability criteria, which include biodiversity protection, of the European Renewable Energy Directive to the global land area and found, for present-day environmental conditions, a potential for an additional bioenergy generation of around 80-90 EJ a-1 on ca. 430 Mha land. A large proportion of this land area is classified as low yielding (low productivity). Regions of high-yield potential that are currently under natural vegetation would be at risk for development unless protective sustainability measures are applied. In a stylised scenario experiment based on data for *Miscanthus* as a bioenergy crop species, half the potential for global bioenergy production was found to lie within the top 30% of land area classified of highest priority for biodiversity protection (Santangeli *et al.*, 2016). In a recent simulation of future land-use impacts on extinction risk of endemic species, and applying land-use change projections adopted from (Popp *et al.*, 2014), the RCP2.6-SSP1 scenario was identified as causing the least loss of natural vegetation cover by 2050 and the least extinctions of endemic mammals, birds and amphibians, compared with the – in this study – "worst case" RCP3.4-SSP4 (Chaudhary & Mooers, 2017). Climate change was not considered as an additional factor, which likely would have enhanced the projected biodiversity risk in the stronger climate change cases. The published literature overall suggests that only protective mechanisms that account for carbon storage potential and biodiversity at the same time could yield the intended carbon-mitigation objectives while avoiding degradation of diversity.

Uncertainties regarding impacts on biodiversity and ecosystems arising from different land-use change projections cannot be assessed yet. It was shown that structural differences (for instance, the type of economic model) that exist between different land-use change models can have a similarly large impact on future land-use change projections than the underlying socio-economic scenario (Alexander *et al.*, 2017c; Prestele *et al.*, 2016). However, only one Integrated Assessment Model provides the so-called marker scenario per RCP/SSP combination (Popp *et al.*, 2014; see **Box 4.2.5**). Without a larger set of harmonised historical to future land-use change projections for each of the RCP/SSP, from a wide range of different land-use change models, the degree to which impacts on biodiversity and ecosystem state and function are related to scenario archetypes remains unresolved.

4.2.4.4 Invasive alien species

Invasive alien species are a major driver of biodiversity loss today (see Chapter 2.2, section 2.2.5.2; see Bustamante *et al.*, 2018; Elbakidze *et al.*, 2018; Nyingi *et al.*, 2018; Wu *et al.*, 2018). Projections of invasive alien species all foresee continued substantial changes in biological invasion state and pressure with significant consequences for both biodiversity and human well-being. These projections have until recently been biased towards climate change related questions, but increasingly also consider how land use and trade patterns might affect future distribution of invasive alien species. Future changes of invasive alien species distributions are still uncertain, but several generalizations can be made from modelling work.

The pressure on biodiversity, and ecosystem function from biological invasions is expected to continue to grow in the coming decades in most parts of the world (Bellard *et al.*, 2013; Gallardo *et al.*, 2017; Hulme, 2009), as well as the economic damage caused by invasive alien species to society (Bradshaw *et al.*, 2016). Extrapolations of cumulative introduction events over Europe suggest that the number of invasive species will continue to increase (CBD, 2014; Elbakidze *et al.*, 2018). This trend is likely to be accentuated at a global scale, as trade between climatically and environmentally similar regions are predicted to increase and habitats continue to be disturbed (Chytrý *et al.*, 2012; Seebens *et al.*, 2015). For example, future hotspots of naturalized plants are predicted to occur mostly in North America, Australia, and South America, followed by Europe, South Africa and China (Seebens *et al.*, 2015). An analysis conducted on the IUCN “100 of the world’s most invasive alien species” suggests future expansion of these species especially in cool temperate areas. The biomes with the highest expected expansion are temperate mixed forest, temperate deciduous forests and coniferous cool forests but also southern Australia, Argentina, as well as Pacific and Caribbean islands due to climate and land-use changes (Bellard *et al.*, 2013). Tropical forest and tropical woodland are projected to be less favorable for those “top invasive” species by 2080. Moreover, some regions will offer more suitable environmental conditions for survival and spread of invasive species compared to current conditions in the eastern part of the United States, northern Europe, Argentina, southern China and India (Bellard *et al.*, 2013). Indeed, poleward migrations of species are expected for many invasive alien species, leading to shifts at higher latitudes of species (Bellard *et al.*, 2013), especially in Europe where shifts are anticipating to reach unprecedented rates of 14-55km/decade (Gallardo *et al.*, 2017). Climate change might also affect establishment of new invasive species indirectly, for instance through changing patterns of human transport or by rendering existing management strategies to defend against invasive species less efficient (Hellmann *et al.*, 2008).

The potential consequences for biodiversity of these future invasions are various. One of the most dramatic consequence is local extirpation of native populations but also species extinctions on islands (Clavero *et al.*, 2009). Invasive mammal species have been a primary cause of extinctions on islands and future impact of those species on insular threatened vertebrates are predicted to increase, if no management measures are undertaken (McCreless *et al.*, 2016). A recent study focusing on Europe showed that protected areas within Europe may offer effective protection to native species against future invasions (Gallardo *et al.*, 2017). Another substantial consequence of biological invasions is the homogenization of fauna and floras which is likely to continue in the future. For instance, continental islands are projected to homogenize greatly beyond current levels of mammal assemblages, while oceanic islands are simulated to experience little additional homogenization of their mammal assemblages (Longman *et al.*, 2018). How many of future introduced species will become invasive is difficult to assess because there is generally a time lag of several decades between introduction, establishment and impact. This time lag also offers a time window for opportunities and actions to mitigate invasions.

4.2.4.5 Pollution impacts on terrestrial ecosystems: Ozone (O_3) and Nitrogen

In response to tropospheric ozone exposure, net photosynthesis declines, either due to the energy needed to produce defence compounds, or the direct damage to the photosynthetic apparatus (Feng *et al.*, 2008; Wittig *et al.*, 2009). Simulations studies result in damage of the order of approximately 10% in annual gross primary production (Franz *et al.*, 2017; Li *et al.*, 2017; Lombardozzi *et al.*, 2012; Sitch *et al.*, 2007) with feedbacks to climate by reduced terrestrial carbon sink strength (Ciais *et al.*, 2013; Sitch *et al.*, 2007). Changes in future species community composition arising from differences in species’ vulnerability to ozone is not possible to project with current modelling tools, although some evidence exists that ozone indeed can affect species composition and richness (see Fuhrer *et al.*, 2016 and references therein). Large regional differences regarding ozone’s future impact on plant communities, carbon or water cycling, or crop yields are to be expected (Franz *et al.*, 2017; Fuhrer *et al.*, 2016; Li *et al.*, 2017).

Eutrophication of terrestrial ecosystems has been found to affect a wide range of ecosystem functioning and community composition across ecoregions (Clark *et al.*, 2017). Nitrogen addition in experimental grassland plots reduced species richness (DeMalach *et al.*, 2017), whereas aboveground plant productivity increases across ecosystems (Greaver *et al.*, 2016). While the key processes operating in the interplay of climate change, N deposition and plant and soil physiology are rather well known, today's modelling tools are inadequate to provide process-based future projections (Greaver *et al.*, 2016). Global projections of the future C sink strength of the terrestrial biota have demonstrated large differences in models that account for C-N interactions, compared to models that ignore these (Arneth *et al.*, 2010; Wårlind *et al.*, 2014; Zaehle, 2013; Zaehle *et al.*, 2015).

4.2.5 Challenges in linking biodiversity and ecosystem functioning at the global level

Linking biodiversity quantitatively to ecosystem function, globally and across large regions, is still a challenge. Species diversity was found to correlate with productivity in (semi) natural systems and in land managed for food or timber (Duffy *et al.*, 2017; Isbell *et al.*, 2011; Liang *et al.*, 2016; Visconti *et al.*, 2018). Likewise in tropical and temperate rivers fish biodiversity correlated positively with fish yields (Brooks *et al.*, 2016). In Amazon forests, carbon storage and turnover were shown to be impacted significantly by tree-mammal interactions (Sobral *et al.*, 2017). In boreal forests, diversity and tree productivity were also correlated (Paquette & Messier, 2011). But global modelling tools to explore in marine, terrestrial and freshwater systems the futures of biodiversity or the futures of ecosystem function are still mostly disconnected (Cabral *et al.*, 2017; Mokany *et al.*, 2016, 2015; Snell *et al.*, 2014; Visconti *et al.*, 2016). This gap reflects the need for connecting model development efforts across scientific disciplines. In the marine field, for example, global scale models of ecosystem function have been mostly developed by physicists, in the form of coupled physics-biogeochemical models representing carbon and nitrogen fluxes between low trophic level functional groups (e.g., phytoplankton, zooplankton), while at the other end of the food web, fish and higher trophic level models have been developed by biologists with far more focus on life history and biodiversity, but embodying simplified forcing of climate, and less global scale perspective (Rose *et al.*, 2010; Shin *et al.*, 2010; Travers *et al.*, 2007).

Global-scale biodiversity modelling has been concerned with a sub-set of challenges, focusing on how future warming will affect the distribution or extinction of species. Interspecific interactions and multi-driver interactions are typically ignored, which can result both in over- and underestimation of risks in diversity losses (Alkemade *et al.*, 2009; Bellard *et al.*, 2012, 2013; Carpenter *et al.*, 2011; Mokany *et al.*, 2016; Pacifici *et al.*, 2015; Pereira *et al.*, 2010; Snell *et al.*, 2014; Visconti *et al.*, 2015). Little attention has been paid to global scale projections of functional, phylogenetic or genetic diversity, even though fast adaptation to environmental changes are possible through microevolution or phenotypic plasticity (section 4.2.1.2; Bellard *et al.*, 2012; Pelletier & Coltman, 2018). Likewise, DGVMS simulate ecosystem state and function, expressed as the stocks and flows of carbon, water and nitrogen (Le Quéré *et al.*, 2018), but with little consideration for interactions between and within groups of plants, or across multiple trophic levels. Potential ways forward to overcome barriers in bridging between models of ecosystem state and functioning, and models that simulate changes in diversity are being proposed in the terrestrial domain (Mokany *et al.*, 2016, 2015; Snell *et al.*, 2014). In the marine domain, integrated end-to-end models start to emerge, resulting from the coupling of disciplinary models of ocean physics, ocean biogeochemistry and fish biodiversity (Fulton, 2010; Rose *et al.*, 2010; Travers *et al.*, 2007). It is expected that approaches towards integrating models of biodiversity and ecosystem function will flourish in the future, despite the multiple technical and conceptual challenges they entail.

Large uncertainties exist both in how impact models respond to climate change and associated environmental drivers (e.g., CO_2 fertilisation, N limitations/fertilization; Ahlström *et al.*, 2012; Ciais *et al.*, 2013; Friend *et al.*, 2014; Gonzalez *et al.*, 2010; Heubes *et al.*, 2011; Huntingford *et al.*, 2009; Rammig *et al.*, 2010; Warszawski *et al.*, 2013; see also section 4.7). Regarding land-use change projections, impacts on biodiversity and ecosystems received so far much less attention compared to climate change (see 4.2.4.2, 4.2.4.3). Futures of other drivers still need to be explored despite of their known large impacts on biodiversity and ecosystems in the past, and today (pollution, invasive species). Moreover, model experiments as well as observational studies tend to concentrate on single-driver responses, despite indications that combined effects cannot be predicted from the sum of single-factor responses (Alkemade *et al.*, 2009; Fu *et al.*, 2018; Langley & Hungate, 2014; Visconti *et al.*, 2015).

Clearly, improvements of scenarios and modelling tools are still needed to be able to represent the future environmental conditions (i.e. the range of conditions that will impact on biodiversity) in a way that is comparable across direct drivers and that enable us to make a fair comparison of their expected impact in the future. For that reason, the overall issue of the relative and combined expected impacts of different drivers in the future remains unresolved.

4.3 PLAUSIBLE FUTURES FOR NATURE'S CONTRIBUTIONS TO PEOPLE

4.3.1 Nature's contributions to people across scenario archetypes

Scenarios and models are important tools for understanding how the multiple contributions of nature to people (NCP) might unfold in the future. Scenarios that are adverse for biodiversity and ecosystem function are likely to be adverse for NCP because of known links between biodiversity, ecosystem function and the material, regulating and non-material benefits to humans (Mace *et al.*, 2012). Nonetheless, there is still a lack of robust knowledge and quantitative estimates of these relationships, and thus how they might impact future changes in NCP.

Scenario archetypes were used to examine the relationship between different socio-economic development pathways and their impacts on the three broad categories of nature's contributions to people (regulating, material and non-material contributions), as interpreted mostly from the ecosystem services literature. Results from the systematic literature review of global and continental-scale scenarios (see Appendix A4.1.1) were classified as falling under "economic optimism" (75 = number of results), "global sustainability" (35), "regional competition" (59), "business-as-usual" (34), "regional sustainability" (14), and "reformed markets" (31) (**Figure 4.3.1**; see also section 4.1.3 for archetype descriptions). Overall, global and continental-scale scenarios addressing NCP are scarce and biased towards a few categories. Some NCP are relatively frequently analyzed such as food and feed, regulation of freshwater and climate;

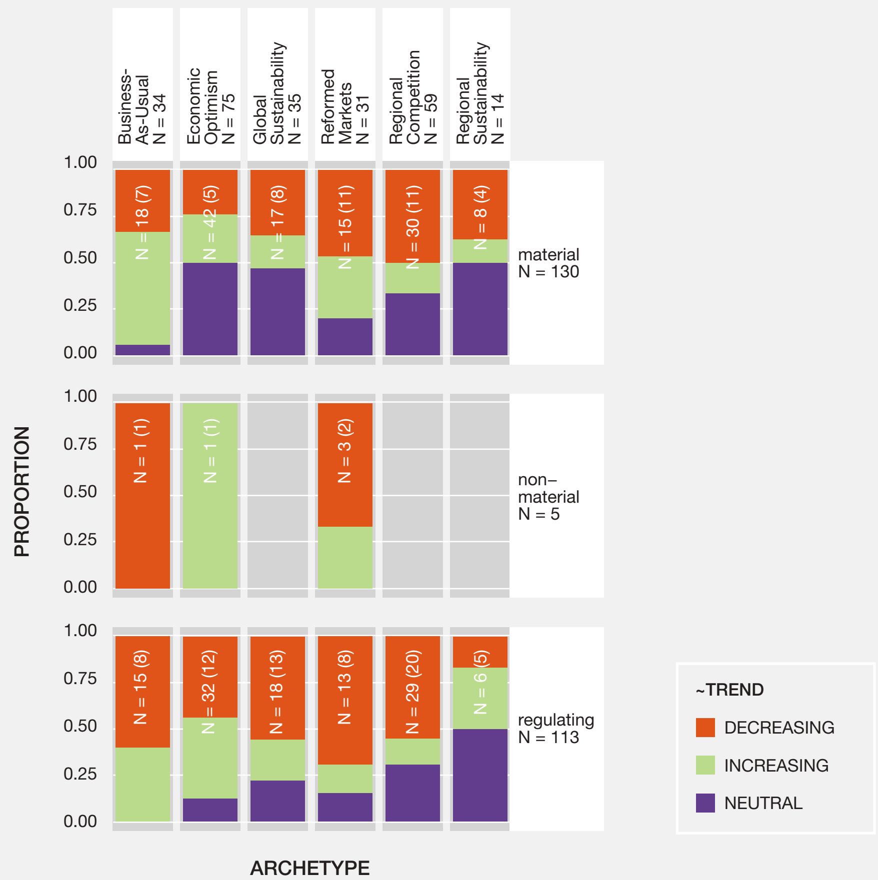


Figure 4 3 1 **Results of the systematic literature review (Appendix A4.1.1) showing the three broad groups of nature's contributions to people (material, non-material, and regulating NCP) for each of the six scenario archetypes.**

The y-axis indicates the proportion of negative and positive trends reported in the literature review. Numbers (N) indicate the number of results, followed by the number of articles that report those results in parentheses.

while non-material NCP or some regulating NCP such as regulation of the impacts of hazards and extreme events and regulation of ocean acidification are covered by a very low number of studies at continental or global scales.

It should be noted that the reviewed literature usually uses the terminology of "ecosystem services" or reports on aspects of ecosystem services without making explicit reference to the ecosystem services framework. Chapter 1 presents a detailed discussion about the relationship between ecosystem services and NCP categories. The literature has been interpreted accordingly, and ecosystem services have been reclassified into IPBES NCP categories. In this section, the term "ecosystem service" is, however, used instead of NCP when it is helpful for clarity and understanding.

4.3.2 Changes in nature's contributions to people

Regulating NCP show decreasing trends in the future in most scenario archetypes **(Figure 4.3.1)**, with only "regional sustainability" and "economic optimism" scenarios showing mixed trends for regulating NCP. "Reformed markets" and "business-as-usual" scenarios present the highest proportion of declining trends for regulating NCP. Material NCP show mixed trends along scenario archetypes. "economic optimism" is the scenario that shows the lowest number of negative trends for material NCP followed by "business-as-usual" and "Global Sustainability". In all cases, published studies focused on the supply of NCP (which is not deconvoluted with the demand of NCP) and did not take into account flows, uses, beneficiaries or values.

Figure 4.3.2 shows the trends for three NCP with the most entries in the systematic literature review database. Food and feed show a mixed picture, while regulation of climate shows a more positive picture and regulation of freshwater a very negative one. This is especially worrisome, because water is the basis for the generation of all other NCP and the direct well-being of humans.

4.3.2.1 Nature's contribution to people – regulating contributions

Habitat creation and maintenance

Habitat creation and maintenance has crucial importance for facilitating all NCP. Considering the projected increasing loss of natural vegetation cover in nearly all future land-use

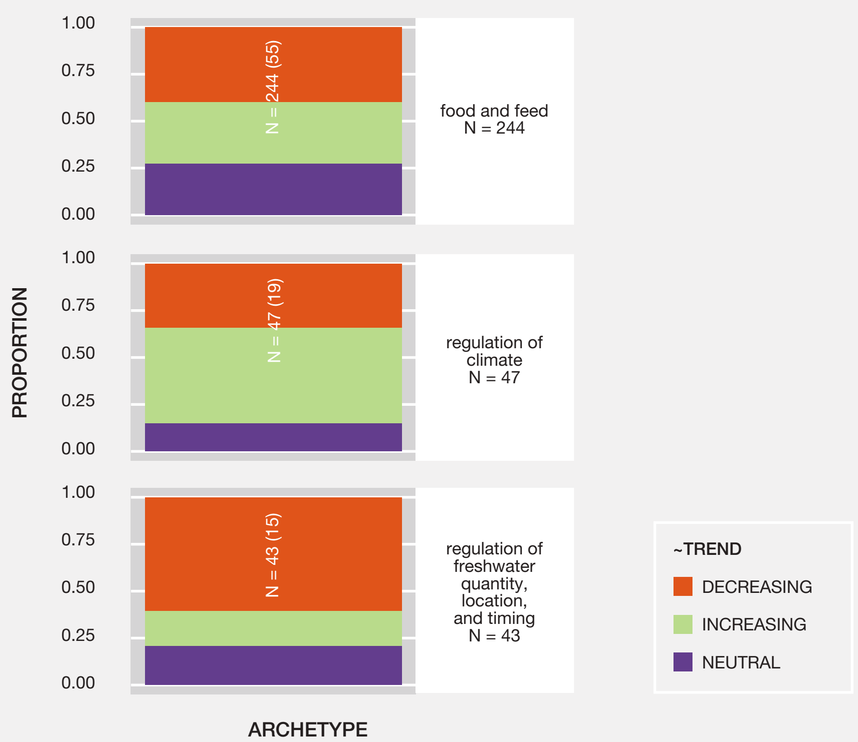


Figure 4 3 2 **Results of the literature review showing the trends for three NCP categories that are the most frequently represented in studies.**

There were insufficient entries to differentiate between archetype scenarios so this figure shows the general patterns over all scenario types.

change scenarios and the climate change induced shift in natural vegetation distribution (see section 4.2.4), it is to be expected that species with specific habitat requirements will be under increasing pressure. Homogenization of communities and habitats is expected to have negative consequences on the ability of ecosystems to maintain multiple ecosystem functions. In addition to habitat specialists, species that can be classified as being intermediate between specialists and generalists will be under increasing pressure, since these species tend to rely on intact metapopulations and are vulnerable to increasing degradation of landscapes. Their loss would have a particularly large impact on genetic diversity since generalist species tend to have more genetic variability compared to specialists (Habel & Schmitt, 2018).

Projections of future interactions between changes in terrestrial habitats and biodiversity focus either on climate change impacts, or on the transformation of natural ecosystems into agricultural systems as main drivers (section 4.2.4; Alkemade *et al.*, 2009; Bellard *et al.*, 2012; Jantz *et al.*, 2015; Mantyka-Pringle *et al.*, 2015; Pereira *et al.*, 2010; Visconti *et al.*, 2016; Warren *et al.*, 2011). At the global scale, little attention has been paid to restoration scenarios. Likewise, most biodiversity and ecosystem models do not have the capacity to represent habitat degradation and fragmentation (Bonan & Doney, 2018). Beyond the use of species distribution models, actual movement of species, either as individuals or as groups is often not taken into account in models used to project interactions between changing environments and populations (Holloway & Miller, 2017), which implies large uncertainty regarding the future vulnerability and/or resilience of habitats and their interactions with the populations these habitats sustain.

Pollination and propagule dispersal

Animal pollination and propagule dispersal play a vital role as a regulating NCP, including for food production and many other ecosystem services. Projected loss of diversity of pollinators and alteration of their communities generate risks for food security, human health and ecosystem function. Pollinators and the provision of pollination will be negatively impacted by land-use change (habitat destruction, fragmentation and degradation), intensive agricultural management and pesticide use, environmental pollution, invasive alien species, pathogens and climate change (Chagnon *et al.*, 2015; IPBES, 2016a; Vanbergen *et al.*, 2018). For instance, the spread of invasive ants that can deter pollinators and seed dispersers is anticipated to continue (see also section 4.2.4) and projected to substantially impact future pollination services (Vanbergen *et al.*, 2018). Impacts of climate change on pollinators are the most commonly reported scenario results. Under all climate change scenarios, pollinator community composition is expected to change. The projected velocity of climate change, especially under mid- and high-end emission of greenhouse gas scenarios, exceeds the maximum speed at which several groups of pollinators (e.g., many bumble bees or butterflies) can disperse or migrate (IPBES, 2016a). Differential phenological shifts can cause mismatches between plant and pollinator populations and lead to the extinctions of plant or pollinator species, with expected consequences on the structure of plant pollinator networks (Hegland *et al.*, 2009; Lavergne *et al.*, 2010; Memmott *et al.*, 2007). However, the inherent plasticity of plant–pollinator interactions suggests that many species may be able to persist, even though their mutualistic partners may change (Burkle & Alarcón, 2011).

Many management responses are available that can reduce the risks of pollination deficit in the short term, including land management to conserve pollinator resources, decreasing pollinator exposure to pesticides, and improving managed pollinator techniques (IPBES, 2016b). The disruption of propagule dispersion due to biodiversity loss is also expected to disturb ecological communities and threaten important ecosystem functions and NCP. For example, frugivore defaunation in tropical forests can lead to local extinction of trees depending on them to reproduce and the induced changes in tree species composition will likely result in the loss of carbon storage capacity of tropical forests (Bello *et al.*, 2015).

Regulation of air quality

Terrestrial ecosystems are large emitters of substances that are relevant for air quality, in particular biogenic volatile organic compounds (BVOC) and emissions from wildfires. Several studies using coupled vegetation and BVOC models show that climate change alone enhances emissions due to their temperature-dependent response (Arneth *et al.*, 2011; Niinemets *et al.*, 2010). However, land-use change is simulated to counteract these effects, in particular for compound groups isoprene and monoterpenes, since woody vegetation tends to emit more BVOC than crops. The effects of rising atmospheric CO_2 are difficult to quantify, because CO_2 enhances productivity which increases emissions, but on the other hand high CO_2 concentrations have been shown to reduce leaf-level emissions – at least for isoprene (Hantson *et al.*, 2017; Heald *et al.*, 2008; Squire *et al.*, 2014; Szogs *et al.*, 2017; Tai *et al.*, 2013). Wildfire emissions, similar to BVOC, are expected to increase in a warmer climate as fire-prone conditions are enhanced (Hantson *et al.*, 2016). In case of fire, atmospheric CO_2 enhances plant productivity, and hence combustible litter, but also leads to a shift towards more woody vegetation, which slows fire spread compared to grasslands (Hantson *et al.*, 2016; Knorr *et al.*, 2016; Rabin *et al.*, 2017). How BVOC and wildfire emissions will affect future air quality and climate regulation will depend not only on how climate change will affect biogenic emissions, but also on how anthropogenic air pollutants will alter biogenic emissions and chemical reactions in a future atmosphere (Shindell & Faluvegi, 2009; Shindell *et al.*, 2009; Tsigaridis *et al.*, 2014; Young *et al.*, 2009). Anthropogenic emission controls are much more important than biogenic emissions for air quality. However, assessments of impacts of bioenergy, reforestation and afforestation efforts on air quality and climate regulation must consider side effects of biogenic emissions on human health and on climate-related substances, as well as (in case of wildfire) the risk of forest loss (Ashworth *et al.*, 2013; Rosenkranz *et al.*, 2015; Simpson *et al.*, 2014).

Regulation of climate

Oceans and terrestrial ecosystems currently take up around 50% of anthropogenic CO_2 emissions each year (sections 4.2.2, 4.2.4; Le Quéré *et al.*, 2016). In the future, these carbon sinks may weaken, resulting in amplifying feedbacks to climate change (Arneth *et al.*, 2010; Ciais *et al.*, 2013; section 4.2.4). In oceans, warmer temperature, increased stratification of the water column, deoxygenation, and acidification, as well as sea level rise in coastal wetlands, might lead to a reduction of the sink (see 4.2.2.2.1, 4.2.2.2.2), while in terrestrial ecosystems, the interplay between CO_2-fertilisation of photosynthesis, heterotrophic respiration stimulated by warmer temperatures, and episodic events such as fire, insect outbreaks, or heat waves are controversially debated with respect to their impacts on future carbon uptake and climate regulation (Ciais *et al.*, 2013; Kautz *et al.*, 2017). Reducing greenhouse gas emissions from land cover change and land use, mostly related to human conversion of forests to crops and pastures, fertilizer use, rice production and animal husbandry could contribute notably to mitigate climate warming (Bustamante *et al.*, 2014; Smith *et al.*, 2014b, 2013; Tubiello *et al.*, 2015). Changes in vegetation cover would impact also regional temperature and precipitation. In tropical regions, deforestation is simulated to lead to local warming, as croplands tend to have considerably lower evapotranspiration. By contrast, in boreal regions changes in surface reflectance is the predominating factor and deforestation results in local cooling (Alkama & Cescatti, 2016). Therefore, in tropical regions, avoiding deforestation will contribute to reduce CO_2 emissions, as well as contribute to moderate the impact of regional warming – supporting also the maintenance of biodiversity (Alkama & Cescatti, 2016; Perugini *et al.*, 2017; Quesada *et al.*, 2017a).

Regulation of ocean acidification

Increasing atmospheric CO_2 concentrations will increase the partial pressure of CO_2 (pCO_2) and its dissolution in the surface ocean (section 4.2.2; Le Quéré *et al.*, 2016). It is expected that pCO_2 might double its pre-industrial value within the next 50 years (Eyre *et al.*, 2018; Hoegh-Guldberg *et al.*, 2017). Decreased calcification in calcified organisms due to increased acidification of the ocean is likely to impact marine food webs and, combined with other climatic changes in temperature, salinity, and nutrients, could substantially alter the biodiversity and productivity of the ocean (Dutkiewicz *et al.*, 2015; Kawaguchi *et al.*, 2013; Larsen *et al.*, 2014; Meyer & Riebesell, 2015). How species will respond to these changes depends on their capacity for adaptive responses. Many studies project the degradation of a large percentage of the world's tropical coral reefs (Albright *et al.*, 2018; Eyre *et al.*, 2018; Sunday *et al.*, 2017 section 4.2.2.2.2) and calcifying marine species like bivalves, might as well be significantly endangered due to ocean acidification (Hendriks *et al.*, 2010; Kroeker *et al.*, 2010). This is projected to impact many regulating ecosystem services and entire sectors of human activities and millions of livelihoods, both in developed and especially in developing countries that depend on fish and other marine products for their daily sustenance (Hilmi *et al.*, 2015; Mora *et al.*, 2013a). Moreover, recreational activities, as well as tourism which are among the world's most profitable industries (Rees *et al.*, 2010) are projected to decline by up to 80% in some areas due to climate change (Moreno & Amelung, 2009; USGCRP, 2008). Although local and regional-scale management strategies may build resilience in the short term, longer term resilience will further require a successful shift to a low greenhouse gas emissions scenario, e.g., RCP2.6 or RCP4.5 (Anthony, 2016).

Regulation of freshwater quantity, location and timing

Today, two-thirds of the global population live under conditions of severe water scarcity at least one month of the year and half a billion people face severe water scarcity all year round (Mekonnen & Hoekstra, 2016). World water demand is estimated to increase significantly, up to 50% by 2030 (UNDP, 2016), mostly due to population growth and lifestyle choices, such as shifting diets towards highly water-intensive foods (see section 4.5.3). Scenarios of water use foresee overexploitation, pollution or degradation of aquatic ecosystems (see 4.2.3) and the ecosystem services they provide or produce together with other ecosystems (Molle & Wester, 2009). Societal problems and new inequalities will also emerge as a result (Bruns *et al.*, 2016). The projected increases in human population and per capita consumption will likely lead to a sharpening of already existing water shortages if the demand of freshwater cannot be satisfied (Alcamo *et al.*, 2007; Murray *et al.*, 2012; Pfister *et al.*, 2011). Some estimates put demand surpassing supply significantly already in 2030 (Mekonnen & Hoekstra, 2016). Changing climate is progressively modifying all elements of the water cycle, including precipitation, evaporation, soil moisture, groundwater recharge, and run-off. But it is also expected to change the timing and intensity of precipitation, snowmelt and run-off (Murray *et al.*, 2012). Indirect effects of land-use change, such as deforestation, is also expected to increasingly affect water quality, water quantity and seasonal flows, especially in the tropics (Piao *et al.*, 2007). Many of the world's most water-stressed areas will likely get less water, and water flows will become less predictable and more subject to extreme events (Mayers *et al.*, 2009; Mekonnen & Hoekstra, 2016). The additional challenges for water security posed by poor management are expected to first become apparent in mega-cities. Increasing demands for water by agricultural, industrial and urban users, and water for the environment will intensify competition (Mayers *et al.*, 2009; Murray *et al.*, 2012; Pfister *et al.*, 2011). In order to address these challenges, water needs to be used more efficiently in agriculture (Fraiture & Wichelns, 2010) and caps to water consumption by river basin have been proposed (Mekonnen & Hoekstra, 2016).

Formation, protection and decontamination of soils and sediments

The Sustainable Development Goals related to food, health, water supply, biodiversity and climate all rely on healthy soils (Arcurs, 2017). Human activity has increased the erosion rates well above natural levels, degrading soils structurally and nutritionally and generating a surplus of sediment transport to rivers, which damages infrastructure, aquatic habitats and deteriorates water quality (Bouchoms *et al.*, 2017; Doetterl *et al.*, 2016; Li & Fang, 2016). Whether or not the eroded material decomposes rapidly or even acts as a carbon sink is still being debated (see Doetterl *et al.*, 2016 and references therein). Climate change is expected to globally exacerbate erosion rates in the future although exact rates and magnitude are poorly understood and large regional variability is to be expected (Li & Fang, 2016). Water erosion caused by overall enhanced precipitation in some regions or by extreme precipitation can be expected to increase (Bathurst, 2011; Bussi *et al.*, 2016; Hu *et al.*, 2013; Shrestha *et al.*, 2013). In a recent compilation of erosion model studies, most at catchment scale, Li & Fang (2016) found enhanced future erosion in response to climate change in 136 of 205 listed studies. Soil erosion can be effectively reduced by land management practices (reduced tillage, vegetation cover) (Doetterl *et al.*, 2016; Poesen, 2018). However, models that combine soil organic carbon cycling with modelling of degradation processes at regional to global scales do not yet exist. Therefore, scenarios of possible futures are virtually absent, and global or sub-global studies could not be found on future soil degradation, nor on soil restoration (IPBES, 2018f).

4.3.2.2 Nature's contributions to people – changes in material contributions

Energy

Ecosystems provide relatively inexpensive and accessible sources of traditional biomass energy, and therefore have a vital role to play in supporting poor populations. Bioenergy draws on a wide range of potential feedstock materials: forestry and agricultural residues and wastes of many sorts, as well as crops or short-rotation forests grown specifically for energy purposes (Smith *et al.*, 2016). The raw materials can be converted to heat for use in buildings and industry, to electricity, or into gaseous or liquid fuels, which can be used in transport. Today's global supply of bioenergy is around 10% of the total demand (Smith *et al.*, 2016). The global demand for primary energy is projected to grow across future scenarios, unless the world's energy system were to transformatively change within the coming two or three decades (IPCC, 2018, Chapter 2.3). Bioenergy is estimated to provide ca. 100-300 EJ a^{-1}, accounting for 15-25% of global future energy demand in 2050, but concerns about the sustainability have been raised even for amounts of 100 EJ a-1 or well below (Beringer *et al.*, 2011; IPCC, 2018, Chapter 2.3; Smith *et al.*, 2016). Deriving about 20-60% of total energy from energy crops would require up to a doubling of land and water resources (Beringer *et al.*, 2011).

Recent scenarios in Integrated Assessment Models that explore options to achieve global warming of 2°C or less include large-scale bioenergy for climate change mitigation (see 4.2.4.3; Bonsch *et al.*, 2016; Smith *et al.*, 2014b, 2016). Combining bioenergy with carbon capture and storage (BECCS) may offer the prospect of energy supply with large-scale net negative emissions, which plays an important role in many low-emission scenarios (Bruckner *et al.*, 2014; IPCC, 2018, Chapter 2; Tavoni & Socolow, 2013). However, there are challenges and risks entailed, as shown by an increasing number of studies, especially around potential conflicts with biodiversity and other NCP (Fuss *et al.*, 2016; Humpenoder *et al.*, 2014; Santangeli *et al.*, 2016; Smith *et al.*, 2016). The use of different sources for bioenergy production will have large impacts on the capacity of energy crop production, climate change mitigation and thus on the trade-offs with other NCP (Gelfand *et al.*, 2013). The trade-offs most often cited are with food production, biodiversity and terrestrial carbon storage (Beringer *et al.*, 2011). Food production will be impacted not only by conflicts in land use as such, but also because of rivalling water use through irrigation of bioenergy crop production (Beringer *et al.*, 2011). Also, the future benefit of CO_2 savings of bioenergy crops is not completely clear, as many studies do not include the emissions of N_2O in crop production that could offset CO_2 savings (Don *et al.*, 2012), or the long-term CO_2 emitted by land conversion or deforestation of natural vegetation to bioenergy crop areas (Don *et al.*, 2012; Krause *et al.*, 2017, 2018).

Food and feed materials

The largest anthropogenic use of land and water is related to the production of food. Also, food production is the largest component of human domination of the global nitrogen and phosphorus cycles (Bouwman *et al.*, 2013).

The drivers are both the food demand (type of diets, wealth and population size) and the food production system (productivity of the agricultural, aquaculture and livestock systems, exploitation of wild species, transport, waste). Rapid changes in dietary patterns since the end of 20th century (mainly in transitioning countries: Latin America, East Asia, others) have become a major factor in global land-use change pressures, mainly related to the increase of animal products consumption (Kastner & Nonhebel, 2010; Kastner *et al.*, 2012). In the coming decades, the increase in consumption of animal products is expected to play the strongest role in the demand of land, water, nutrients (N, P, K) and energy (and related CO_2 emissions) for food production (Alexander *et al.*, 2016; Peters *et al.*, 2016; Ranganathan *et al.*, 2016; Wirsenius *et al.*, 2010), due to the poor resource efficiency in the production of animal, especially ruminant protein. Therefore, land degradation and its impacts on food security are likely to increase, especially in developing regions with high and increasing demographic pressure, pressures from export-oriented commodity production expansion, scarce land and water resources and weak governance structures. Importantly, effects of land degradation on food security are not considered in any global scenario study (IPBES, 2018f). For sufficient land and water resources being available to satisfy global food demands during the next 50 years, water will have to be managed much more effectively in agriculture (Fraiture & Wichelns, 2010). Supplying sufficient calories and an overall healthy diet to feed the global population with sustainable production systems is a recognized challenge and will require solutions from local to global levels, addressing both food production, distribution and trade, and consumption (Foley *et al.*, 2011; Godfray *et al.*, 2010; Tilman & Clark, 2015). Closing yield gaps in many regions of the world may play a major role if done using sustainability principles for land management. This poses a large challenge as climate change has been projected to reduce crop yields in tropical and semi-arid regions; regions in which already today large yield gaps exist (Pugh *et al.*, 2016a; Rosenzweig *et al.*, 2013) and which include countries with projected fast changes in diets and population growth. There is large uncertainty in how extreme weather events, pest and diseases and atmospheric CO_2 levels will interact with yields (Deryng *et al.*, 2014; Gornall *et al.*, 2010; Rosenzweig *et al.*, 2013). Thus, it is necessary to increase productivity sustainably and at the same time reduce the vulnerability of agricultural production systems to climate change impacts.

Medicinal, biochemical and genetic resources

Because genetic diversity of crops and their wild relatives is a product of both the natural process of evolution and the biocultural process of evolution under domestication, genetic diversity is a source of, and a proxy for options for the future, and hence maintains options for the supply of ecosystem services (Bellon *et al.*, 2018; Faith *et al.*, 2017). However, if yields continue to be increased by means of intensive agriculture, then the environmental consequences would be substantial (Tilman *et al.*, 2001) and to the detriment of other NCP (section 4.5). The current diet worldwide is based on only 150 of the more than 7,000 plant species that humans have utilized historically for food (Gepts, 2006) and food supplies have become increasingly similar in composition across the globe (Khoury *et al.*, 2014).

The conservation of genetic resources from local varieties and crop wild relatives plays an important role in increasing productivity sustainably, maintaining local food security and quality, as well as in providing adaptive options for agricultural systems to grow diverse and nutritious food with fewer resources in harsh environments. For instance, cultivars based on local varieties can be grown in marginal conditions where commercial varieties do not perform well (Ceccarelli, 2009), and crop wild relatives harbor genetic adaptations to drought, pest and diseases resistance (Maxted *et al.*, 2013). Therefore, genetic diversity represents a source of options to face the increasingly uncertain and variable patterns of biotic and abiotic changes (Bellon *et al.*, 2017). Similarly, deploying sufficient genetic diversity decreases the risk of pathogens reaching epidemic levels and causing large-scale crop failure (Heal *et al.*, 2004).

Indigenous Peoples and Local Communities play an essential role in this regard both in managing key agrobiodiversity areas around the world and holding the knowledge that gives meaning to the value of such diversity. Maintaining in-situ crop genetic diversity is at present done mostly by smallholders and indigenous communities, cultivating local varieties individually in small-scale mosaic production systems, but these constitute in many regions large effective systems in providing food to large regional populations within a wide range of environmental conditions and cultural preferences (Bellon *et al.*, 2018; Enjalbert *et al.*, 2011). If trends towards replacing local varieties with genetically homogeneous materials of the private sector continue (Heal *et al.*, 2004; Howard, 2009), evidence suggests that while crop production yield may increase (particularly for crops destined to industrial uses and fodder), food security may be compromised not only in terms of lower crop production of food crops, but also in the form of higher risk and vulnerability of farmers and the food system to future challenges.

4.3.2.3 Nature contributions to people – changes in non-material contributions

The results of the systematic literature review highlight the scarcity of global or continental scale scenarios addressing non-material contributions to people: these have received far less attention than material and regulating NCP. Even on the local scale, the number of scenario studies dealing with the category of cultural ecosystem services is limited.

The sections below describe how different non-material NCP might unfold in the future based on scenario studies at different scales, including some local studies. In order to arrive at a better understanding on how changes in nature and changes in people's demands interact for all NCP, future studies that target non-material NCP are needed.

Learning, artistic, scientific and technological inspiration

The published literature on the future evolution of this category of NCP is scarce with most studies focusing on the current state of nature-inspiration for learning, the arts, science and technology. Nature inspiration for the arts, including music, painting and literature comes ultimately from the fact that we are part of nature, and that when we are amazed by certain aspects of nature, this inspires individuals to express their creativity (Komorowski, 2016). Whether the ongoing disconnection of humans from nature (Soga & Gaston, 2016) will affect how art is inspired by nature in the future is unresolved. Nature-inspiration has advanced technology in multiple ways, the Lotus effect or the shark skin effect being some of the most common examples (Bhushan, 2016). Nature inspiration has played a significant role in computation and communication and it is likely that it will continue doing so (Vinh & Vassev, 2016). The self-organized architecture of nature can play a major role in nature-inspired algorithms and computing (Yang, 2014, 2010). Bioinspiration and biomimetics in engineering and architecture has a long history of application, but its future development is uncertain (Ripley & Bhushan, 2016).

Physical and experiential interactions with nature

Connections to nature have been classified as being material, experiential, cognitive, emotional, and philosophical (Ives *et al.*, 2018). Partially as a result of rapid urbanization (see section 4.3.3 and Jiang & O'Neill, 2017) some argue that urbanites are undergoing an "extinction of experience" resulting from decreasing contact with nature in everyday live (Soga & Gaston, 2016). Although varying significantly across and within regions, interactions with nature have been changing from direct subsistence interactions (i.e. through agriculture, farming, fishing, hunting, herding, foraging) to sporadic subsistence, leisure, education, or as health-recommendation. This trend is expected to continue in the future although other forms of interaction with nature are also emerging, such as increasing attention to urban parks, river and lake restoration projects, urban gardens, and increasing green infrastructure in cities (Grimm & Schindler, 2018; Shanahan *et al.*, 2015; Thompson *et al.*, 2008). Indicators to assess interactions with nature are scarce. Visits to protected areas have been estimated at 8 billion per year (Balmford *et al.*, 2015) with a generally increasing trend (except for some developed countries (Balmford *et al.*, 2009), but it is unclear how this figure will evolve under different scenarios. Apart from protected areas, direct interactions with nature occur in many non-protected landscapes, from urban parks, to rural areas and remote landscapes. These interactions are more widespread than visits to protected areas and happen continuously.

The main drivers expected to affect future physical and experiential interactions with nature through nature tourism are demographics, urbanization, climate change, technology, psychological drivers, health care trends and development (Frost *et al.*, 2014). A warmer future may increase the visits to protected areas, especially to mountain protected areas where temperatures are cooler (Fisichelli *et al.*, 2015; Steiger *et al.*, 2016). In some areas, a business-as-usual scenario might reduce our interactions with nature due to the loss of natural ecosystems through deforestation. Local scenarios in the Eastern Arc Mountains in Tanzania show that non-sustainability pathways would also reduce ecotourism (Bayliss *et al.*, 2014). Participatory scenario planning approaches in which stakeholders co-develop different scenarios have been used in several local studies and assessed future trends of diverse non-material NCP such as interactions with nature (Oteros-Rozas *et al.*, 2015). Future trends for ecotourism, for example, were analyzed through the integration of ILK and scientific knowledge for a case study in Papua New Guinea (Bohensky *et al.*, 2011b).

Symbolic meaning, involving spiritual, religious, identity connections, social cohesion and cultural continuity

Among the very few existing scenario-based studies that specifically focus on this nature's contribution to supporting identities (Díaz *et al.*, 2018), some focus on sense of place, which is highly relevant for ecosystem service stewardship and for human well-being, particularly of IPLCs (Masterson *et al.*, 2017). Some analyses suggest that climate change might negatively affect sense of place (Ellis & Albrecht, 2017), an issue of concern to an increasing number of people living in coastal areas and under increasing risks such as floods and sea level rise will increase (Neumann *et al.*, 2015). Sense and forms of attachment to place are also negatively affected by changes caused by infrastructural responses, such as the need to construct flood defenses (Clarke *et al.*, 2018).

Identities that are linked to nature, such as those related to cultural keystone species, will probably decline under certain scenarios (Garibaldi & Turner, 2004). In business-as-usual scenarios indigenous identities are expected to decrease, as these are often linked to nature, and Indigenous People´s spiritual beliefs (Dudgeon *et al.*, 2010). Hunting practices that have deep cultural meanings for some local communities and help to bound some societies might be affected as well (Luz *et al.*, 2017). In cities, declining green space might produce feelings of loneliness and shortage of social support (Maas *et al.*, 2009). Connecting theories and tools related to sense of place within broader socio-ecological systems research is expected to enhance our understanding as to how and why people engage in solving challenges related to sustainable use of ecosystems (Masterson *et al.*, 2017).

Preservation of biodiversity and ecosystems, as options for the future

One of the challenges posed by the expected continuous degradation of ecosystems and loss of biodiversity in most scenario archetypes is to assess the implications of these trends in terms of options for the future (Pereira *et al.*, 2010 and see section 4.2). Local level examples **(see Box 4.3.1)** highlighting the interdependence between nature, indigenous and local knowledge, and local livelihoods provide powerful stories about economic-environmental trade-offs and the importance of maintaining options, including in terms of complementary knowledge systems, in times of accelerated environmental and social changes.

Box 4 3 1 **An example of the role of Indigenous Local Knowledge in sustaining ecosystem services.**

The shea tree is highly valued by rural households in Western and Central Africa. The shea fruit is a non-timber forest product that is indigenous to ecosystems in semi-arid regions of Africa (Jasaw *et al.*, 2015). Shea is exported as raw kernels or as shea butter to serve the high-value cosmetic and personal care industry and the wide range of food products in USA, Europe, and Japan. It currently grows throughout semi-arid northern Ghana (CRIG, 2007; Naughton *et al.*, 2015), with almost every rural household in the region engaging in shea fruit picking, and processing into shea kernels (shea nuts) and/or shea butter. For years, local populations have followed local knowledge, norms and practices including not using shea for fuelwood and integrating it into farmlands to preserve and manage it (Jasaw *et al.*, 2015). In recent years however, high disregard for indigenous knowledge practices, degradation and subsequent scarcity of traditional fuelwood tree species, and fluctuating world market prices for shea products, have pushed locals being faced with the dilemma of still preserving the tree to enable them earn income or cut the trees for fuelwood (Boafo *et al.*, 2016; Jasaw *et al.*, 2017). If current trends continue, the co-production of the shea butter will continue eroding indigenous and local knowledge (ILK), the management of common resources, as well as regulating and non-material contributions from nature to people. Both technological improvements (such as improved stoves) and the strengthening of community-based woodland management (such as harvesting tree branches instead of whole trees) need to be put in place to revert this trend (Boffa, 2015; Jasaw *et al.*, 2017, 2015).

Figure 4 3 3 **Woman taking shea harvests home to process.**

Photo credit: Yaw Boafo, 2014.

Figure 4 3 4 **Woman sorting shea kernel for sale in Northern Ghana (left); Shea kernel being dried after picking from the wild in Northern Ghana (right).**

Photo credit: Yaw Boafo, 2014.

Future scenarios of climate change predict in this case an increased climate suitability for the shea tree (Platts *et al.*, 2010). This could open certain opportunities to adapt to climate change and at the same time reinforce the value of ILK in landscape management. Since the traditional form of Shea butter production also requires large amounts of energy (Jasaw *et al.*, 2015), six scenarios of future development of technologies were developed for Burkina Faso (Noumi *et al.*, 2013). The improvement of the energy systems would result in better incomes for women and reduced vulnerabilities of rural families whilst minimizing land degradation and enhancing carbon sequestration potential of savannah landscapes.

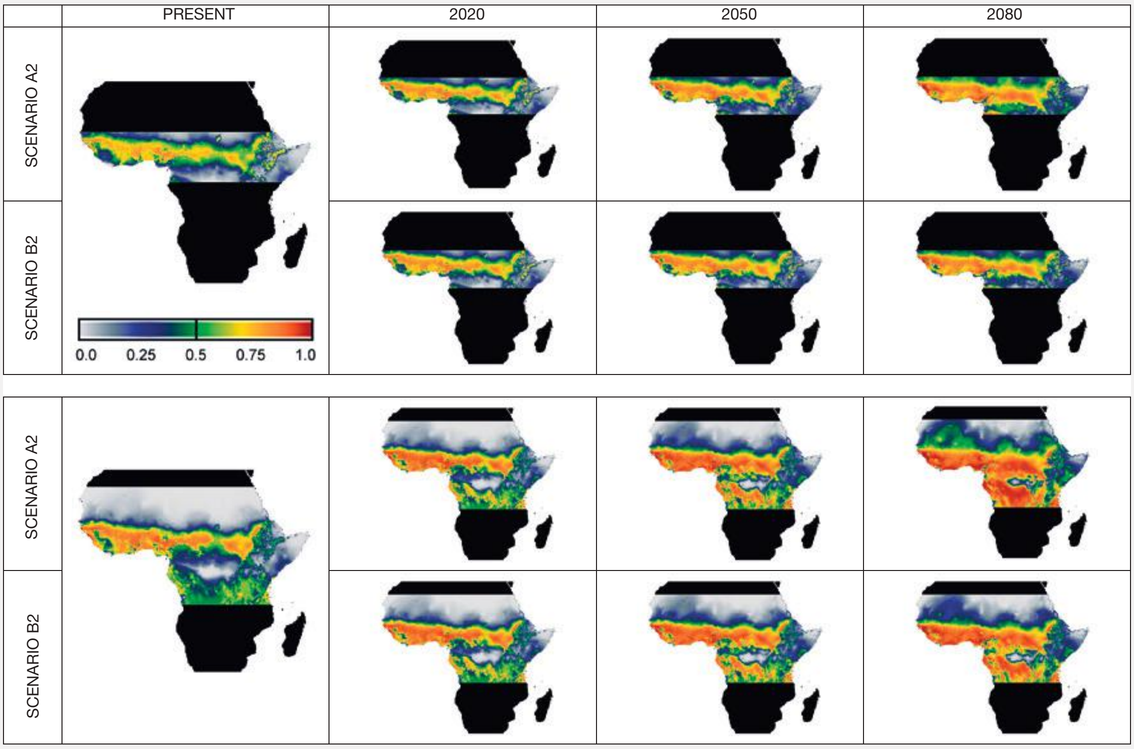


Figure 4 3 5 **Present situation and future scenarios of the climatic suitability for the distribution of the shea tree.**

In both scenarios, niche-based models predict an enhanced climatic suitability for the shea tree during the 21st century (Platts *et al.*, 2010). Top panels are projections based on a restrained geographical range for model calibration and lower panels are based on a broader geographical range. The suitable habitat for the shea tree in central Africa is projected to increase in two explored IPCC scenarios (A2 and B2) in 2020, 2050 and 2080. According to these scenarios, the maximum suitability is predicted for 2080.

4.3.3 How changes in nature's contributions to people will manifest in different regions, including teleconnections across regions

Ecosystems and biomes (or IPBES units of analysis) are interconnected, influence each other and thus many NCP are also interconnected in space (Álvarez-Romero *et al.*, 2018; Liu *et al.*, 2015). These interactions can occur in the natural system (e.g., via the atmosphere, or through river flows), often called teleconnections. In socio-economic and socio-ecological systems the telecoupling concept considers interactions, feedbacks and spillover between different and typically distant system components (e.g., by trade or migration; Güneralp *et al.*, 2013; Liu *et al.*, 2013; Melillo *et al.*, 2009). Through those mechanisms, resource use and ecosystem management in some regions affects NCP from other regions (Pascual *et al.*, 2017; see section 4.5 and Chapter 5). For example, the displacement of timber extraction from Finland to Russia has created environmental impacts in Russia that in turn affected migratory birds in Finland (Mayer *et al.*, 2005).

Knowledge about the interaction, feedback and spill-overs among regions, and implementation in future global scenarios is needed for better projections and management of NCP including flow-based aspects of governance beyond the classical territorial approaches (Liu *et al.*, 2013; Sikor *et al.*, 2013). Without such knowledge, decisions on the management of NCP in one region will lead to incomplete and skewed conclusions that affect sustainability at the global level (Schröter *et al.*, 2018). For example, telecoupling is linked to remote, large-scale investment in land purchase or lease and freshwater demand, which is happening in all continents except Antarctica (Rulli *et al.*, 2013). Also in context of urban-rural relations this consideration can help to better understand interactions with systems beyond their boundaries (Seto *et al.*, 2012).

Urbanization is one of the global development trends that has large impacts on local and distant socio-ecological systems. The global urban population represents now 55% of the total population and is projected to reach 6.6 billion by 2050 (68% of the total population) (https://population.un.org/wup/).

In the vicinity of cities, urban growth leads to the loss of agricultural land and hence agricultural production, and associated land-use displacement to other regions as compensation. Overall it is estimated that, due to urban build up, 1.8–2.4% of the global croplands will be lost by 2030 (Bren d'Amour *et al., 2017)*. On local and regional level urban areas modify climate through the urban heat island effect, impacting also human health. In combination with altering of precipitation patterns, the heat island effect will possibly also have significant impacts on net primary production, functions of ecosystems, and biodiversity in larger urban regions (Seto *et al., 2013)*. Urbanization also frequently correlates with lifestyle and dietary changes towards more meat and fish (Satterthwaite *et al., 2010)*. As a result, long-distance connections intensify as demand for resources increases to support these urban lifestyles and activities. Often such change in demand is not only met by intensification but also by cropland expansion into semi-natural or natural vegetation (DeFries *et al., 2010)*, which in turn may lead to the displacement of local farmers due to loss of land and increases migration to urban areas.

There are very few global scenario studies of telecouplings, and the related interactions between nature and NCP. For instance, most forward-looking studies on impacts of urbanization on ecosystems focus on impacts on biodiversity and habitats (Güneralp *et al.*, 2013). There are no quantitative studies and scenarios that assess interactions of urban areas with ecosystem services at global and large spatial scales and there are only a few, mostly scenario-based, regional studies from developed countries (Deal & Pallathucheril, 2009; Eigenbrod *et al.*, 2011; Norman *et al.*, 2010; Pickard *et al.*, 2017). Virtual water import/export has been explored under future scenarios under climate change, stressing local water losses due to trade links (Konar *et al.*, 2013; see also Chapter 5). For instance, continued increased consumption of meat or milk in China would have negative consequences on the virtual water imported by the country (Zhuo *et al.*, 2016), as well as higher greenhouse gas emissions and land use in milk exporting regions (Bai *et al.*, 2018). Results from the systematic literature review regarding future trends of various NCP in different world regions and the interlinkages between them do not show clear trends for many NCP because of the limited number of studies **(Figure 4.3.6)**. Mixed trends prevail for regulating NCP in most parts of the world, with slightly more increasing trends in North America, Europe, and Australia. Material NCP are expected to mainly decrease in Central America, in Southeast Asia and Australia, stabilize in South America, South Asia and East Asia; a higher proportion of increasing material NCP are expected in Europe and North America. Not much data on non-material NCP is available but positive trends in Africa and Asia could emerge, while in South America the expected trends were mostly negative.

In addition to the systematic literature review, we reviewed the IPBES regional assessments (IPBES 2018a, b, c, d) for relevant information of future trends of telecoupled interactions.

The IPBES regional assessment for Europe and Central Asia (IPBES, 2018i) highlights a variable but generally decreasing supply of regulating NCP in Europe (Harrison

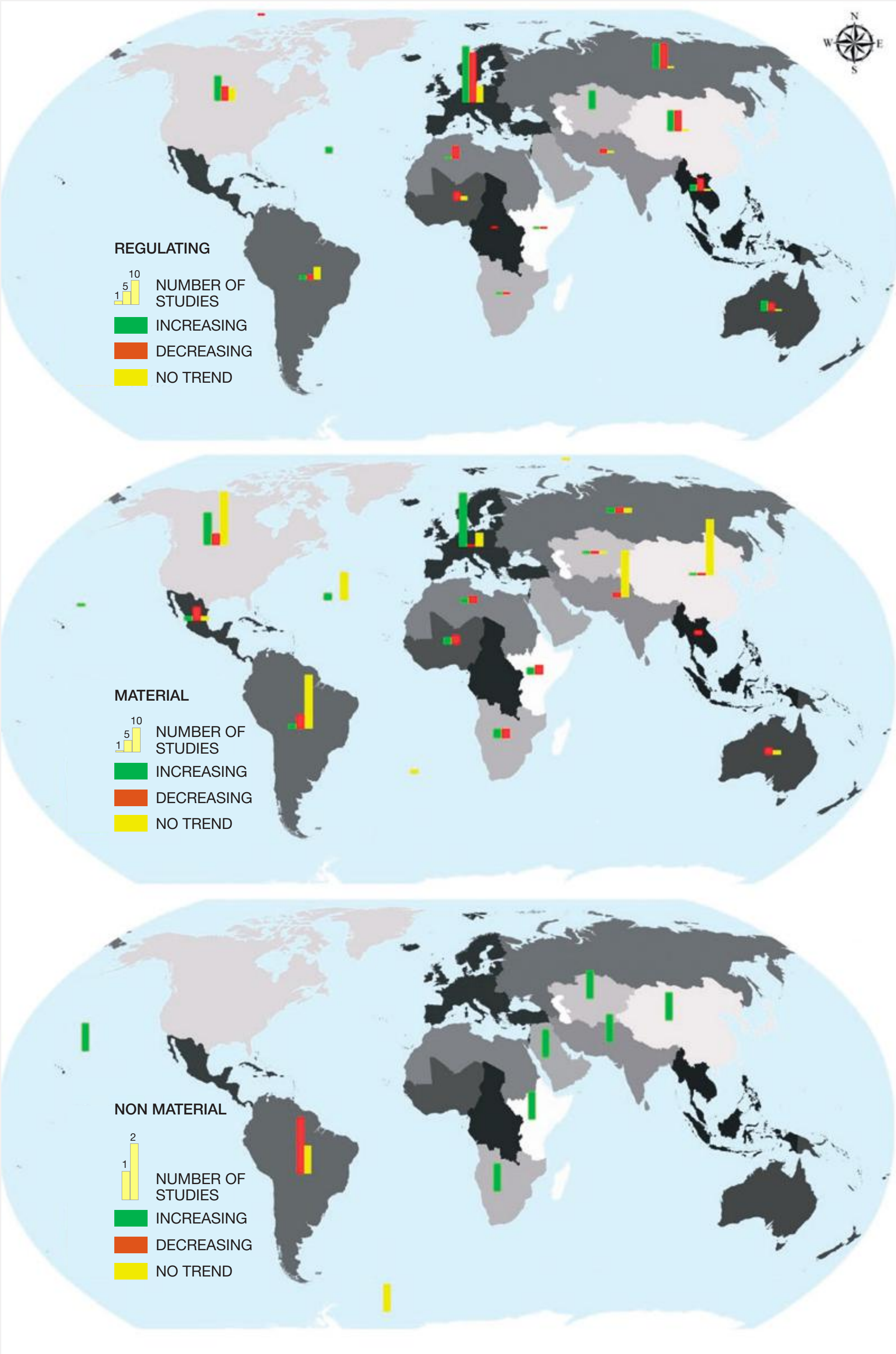


Figure 4 3 6 **Future trends of NCP in the different world regions.**

The height of the bars indicates the number of studies. The color of the bars shows the sign of future trend of NCP in the different world regions (IPBES regions shown in grey scale). Results are based on the systematic literature review of future scenarios (Appendix A4.1.1) at the continental scale. Only the studies with an explicit distinction of NCP trends between countries or regions were selected.

et al., 2018). Hazard regulation, climate regulation, water quality and quantity regulation show stable or increasing trends, whereas regulation of freshwater quantity, location and timing decreases, especially in Southern Europe. Pollination and pest regulation indicate mixed trends. Regarding material NCP, the results vary across subregions. An increase of food and feed is expected in western Europe due to increasing imports from other world regions (Dunford *et al.*, 2015). Eastern Europe and Russia show increasing trends in food production, due to the increase in suitability for food production following climate change (Zabel *et al.*, 2014). Information on non-material NCP is scarce (Harrison *et al.*, 2018).

The demand of material NCP in Europe, especially food and feed, materials and energy could increase up to 1.5-2 times, which not only means an increase in material NCP but will have considerable trade-offs with biodiversity and regulating NCP (Harrison *et al.*, 2018). According to the BAU scenario, food production will be the economic sector with the largest impact on biodiversity, possibly contributing to 60-70% of terrestrial biodiversity loss and 50% in freshwater systems (Kok *et al.*, 2014; van Vuuren *et al.*, 2015). Other scenarios, such as the global technology, decentralized solutions and consumption change would result in preventing more than half of the loss of the biodiversity that is projected for 2050. Other models show that domestic greenhouse emissions can be reduced affordably by 40% in 2030, but would require strong policies and binding targets, and possibly the use of biofuels, which have associated negative effects on biodiversity (Harrison *et al.*, 2018).

In Africa a lack of studies that assess the future of NCP is apparent and the few existing ones focus on Southern and East Africa (Biggs *et al.*, 2018). The systematic literature review shows that in different regions of Africa, the demand for food and feed will lead to an increase of this NCP, despite the pressure arising in many regions from climate variability and change (Palazzo *et al.*, 2017). Scenarios show that increased water stress will have most adverse effects on food production, as areas suitable for agriculture along the margins of semi-arid and arid areas are expected to decrease (Biggs *et al.*, 2018). An estimated 600,000 km^2 of arable land could be lost with 800 million people facing physical water scarcity. Rising sea levels will pose threats to Gambia around to the Gulf of Guinea and a predicted band of desiccation will wrap around the Congo Basin from the Gambia to Angola (Biggs *et al.*, 2018). Given the general trade-off between material and regulating NCP, a decrease in the supply of regulating NCP is expected. In Sub-Saharan Africa, bans on food imports would negatively impact poverty (Bren d'Amour *et al.*, 2016).

Existing scenarios with information for NCP in the Americas focus on the strong competition among land uses, primarily agricultural lands and natural land cover (Klatt *et al.*, 2018). The demand for food and feed will increase in the future with strong trade-offs for regulating NCP (e.g., water quality, increased greenhouse gas emissions, disruptions of natural pest control, pollination, and fertility and nutrient cycling; Diaz & Rosenberg, 2008; Matson *et al.*, 1997). Co-benefits may occur, like e.g., incorporating biodiversity in agricultural production systems (Baulcombe *et al.*, 2009; Chappell & LaValle, 2011; Clay *et al.*, 2011; de Schutter, 2011; Perfecto & Vandermeer, 2010). The supply of regulating NCP provided by natural ecosystem decreases under all scenarios (even under conservation scenarios), especially through tropical deforestation in Latin America, which is projected to continue. A similar pattern can be observed also for other ecosystems, like tundra, mangroves or wetlands. The decrease in supply of regulating NCP means that the tundra may convert from a carbon sink into a carbon source under the temperature increase that thaws the permafrost, leading to a feedback to accelerated climate change and sea level rises. The same applies for the prevention of soil erosion, coastal protection and fisheries support of mangroves. Also, the regulating services of wetlands may get traded by agricultural productions under the strong increase of population and other market forces. An example is the Amazon forest, where especially cattle ranching together with agriculture leads to deforestation, leading to a synergistic drying up of large parts of the watershed due to climate change (Klatt *et al.*, 2018).

In the Asia-Pacific region, expansion of urban industrial environments, consumption patterns and transformation of agriculture in favor of high yielding varieties and cash crops are the main drivers for changes in NCP, considering the current rate of human population growth (Gundimeda *et al.*, 2018). The demand for material NCP is projected to increase, especially for food and feed in Southeast Asia and South Asia, leading to deforestation for monocrop plantations of oil palm, rubber or timber trees. This may lead to a decrease in the supply of some regulating NCP, and natural habitats in the Asia Pacific Regions are likely to be adversely affected in the coming decades (Gundimeda *et al.*, 2018). Telecouplings are very pronounced, especially within Southeast Asia (e.g. Vietnam- Laos) and between mainland Southeast Asia and North Asia, as between Southeast Asia and Latin America and Africa. Regarding other regulating NCP the results are mixed with increases and decreases in all subregions (IPBES, 2018h).

4.4 PLAUSIBLE FUTURES FOR GOOD QUALITY OF LIFE

4.4.1 Linking good quality of Life to nature and nature's contributions to people

Global scenarios of biodiversity and ecosystem services have paid scarce attention to plausible futures for people's good quality of life (GQL), relative to those for nature and nature's contributions to people (but see Butler & Oluoch-Kosura, 2006). This gap is further pronounced for the analysis of future trends for the quality of life of Indigenous Peoples and Local Communities (IPLCs), who have been addressed typically at local and subnational scales rather than at the regional to global scales. However, a recent assessment of scenarios and models of ecosystem services and biodiversity brought to light some of the plausible futures of GQL (IPBES, 2016b), while earlier assessments highlighted the dependency of human beings on ecosystems for well-being and socio-economic development (MA, 2005; UK National Ecosystem Assessment, 2011).

To complement these efforts, in this section we seek to show how good quality of life has been integrated in the assessment of plausible futures of nature and nature's contributions to people. To this end, we address how eleven key material and non-material dimensions of GQL (see also Chapter 1) are expected to evolve under the different archetype scenarios, and highlight the role of access, social values and other factors mediating the relationship between nature's contributions to people and good quality of life.

4.4.1.1 Key Dimensions of good quality of life and their links to nature and nature's contributions to people

4.4.1.1.1 Material dimension of good quality of life

In future scenarios governed by market forces (e.g., economic optimism, business-as-usual; see Section 4.1), multiple dimensions of good quality of life (GQL), both material and non-material, can be expected to decline **(Figure 4.4.1)**. These projections are based on narratives associated with specific archetype scenarios, with numeric scores above zero indicating an anticipated positive (increased) GQL for the selected indicator, and negative indicating a decline. Projected declines are particularly pronounced for material indicators relative to livelihood and income security. The regional competition scenario, in particular, is assumed to be associated with the lowest expected GQL outcomes. On the other hand, the regional sustainability and reformed economic markets scenarios are expected to result in improved GQL outcomes across a large cross-section of material and non-material indicators. Overall, the global sustainable development and regional sustainability scenarios are associated with the most desirable GQL outcomes. Scenarios of direct and indirect drivers of change are expected to have regionally differentiated impacts on GQL, including where Indigenous Peoples and Local Communities (IPLCs) are located (see examples below). Many IPLCs are found in protected areas and indigenous areas where dimensions of a GQL such as food and energy security play out in context-specific ways. Indirect drivers of change such as climate mitigation policy (e.g., REDD+) disproportionately impact the possible trajectories towards achieving GQL by IPLCs (sections 4.1.4, 4.1.5).

Food and nutritional security

The 2018 annual report on the State of Food Security (http://www.fao.org/state-of-food-security-nutrition/en/), assessed that world hunger is on the rise again with the number of undernourished people having increased to an estimated 821 million (2017), compared with 804 million in 2016 and 784 million in 2015, although still below the 900 million reported in 2000. Future projections raise important concerns about global food security and indicate widespread disparity in its outcomes, estimating that between 5 million and 170 million people will be at risk of hunger by 2080 (Schmidhuber & Tubiello, 2007). With continuing urbanization of the global population (see section 4.3.3), much of this burden can be anticipated to be borne by the urban poor, especially in the developing south. Food security is related to cultural rights and human rights, and to processes of community change such as out-migration and livelihood shifts (e.g., changing migration patterns may leave fewer young people to hunt and fish, and elders often too old to engage in these activities). Access to resources (including financial resources) are also needed to participate in traditional activities securing access to food. Future food security scenarios refer to at least one of the four key dimensions of food security: availability, access, utilization and stability (FAO, 1998). All four dimensions are expected to be affected by climate change, although only food availability is commonly considered by simulation studies with a wide projected range of impacts across regions and time depending on the socio-economic context (Brown & Funk, 2008; Schmidhuber & Tubiello, 2007). The systematic literature review conducted in this chapter (Appendix A4.1.1) portends strong negative trends for food security in future scenarios **(Figure 4.4.3)**. The IPCC Special Report on Emission Scenarios (SRES) depicted cereal production, cereal prices and food security under three conditions: no climate change, climate change with CO_2 fertilization effects, and climate change without

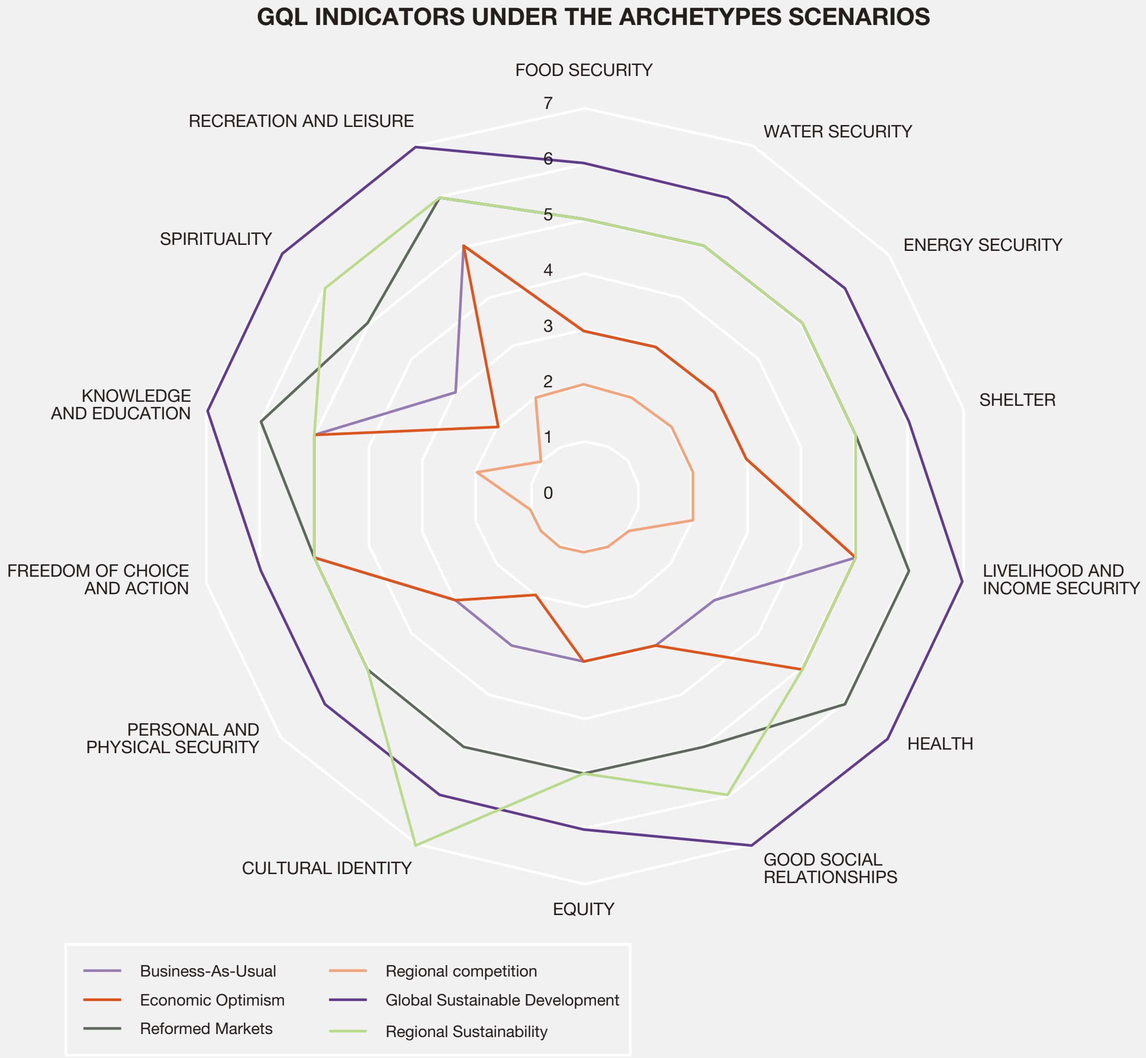


Figure 4 4 1 **Dimensions of Good Quality of Life (GQL) under archetype scenarios based on the narratives of these scenarios, taking also into account Table 6.3 of the IPBES methodological assessment of scenarios and models of biodiversity and ecosystem services (Cheung *et al.*, 2016).**

The numerical scale (-2.5 to 2.5) refers to the progress from "very negative" status = -2.5 to "very positive" status = 2.5 in the corresponding GQL indicator. More detailed information is found in the Appendix, Table A4.4.1.

CO_2 fertilization effects (Parry *et al.*, 2004). Under the assumption of no climate change and increasing yields due to technological change, it was estimated that cereal prices would increase due to an increase in global income. With climate change, food shortages were expected to drive up food prices. The MA scenarios projected an increase in total and per capita food production but variation in food prices, calorie availability and child malnutrition were also to be expected (Carpenter *et al.*, 2006). More recent work agrees that the impact of climate change on food security varies across time, space and subpopulations. For instance, food insecurity is expected to be more severe in the Amazon floodplains (Oviedo *et al.*, 2016; Vogt *et al.*, 2016), polar regions such as the Arctic Bay (Pearce *et al.*, 2015) and the Pacific Islands (McMillen *et al.*, 2014). Small-scale farming, fishing and other communities that depend directly on local environments for food production (McDowell & Hess, 2012) especially in developing countries, indigenous communities (Huntington *et al.*, 2016), or First Nations (Golden *et al.*, 2015) are particularly vulnerable to climate-related food insecurity. A synthesis across a number of international assessments integrated and grouped factors impacting food security **(Figure 4.4.2)** and identified that in these assessments the individual factors underpinning food security were mostly not linked to other relevant factors, i.e. indicating substantial gaps in our understanding of the food

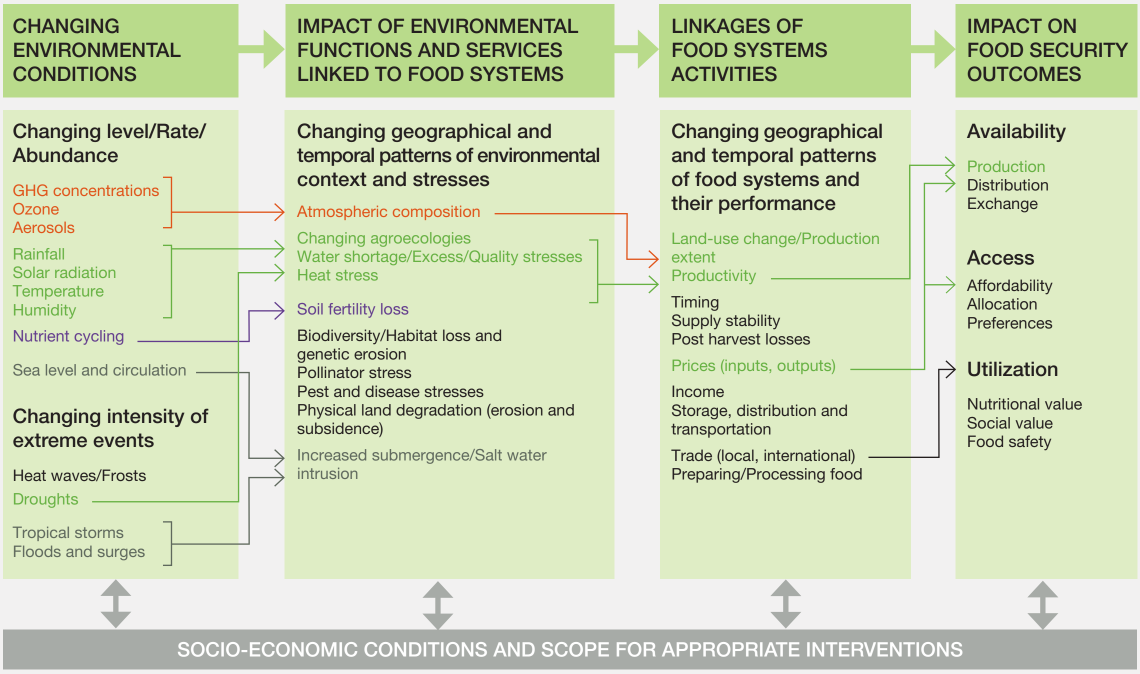


Figure 4 4 2 **Food Security impacts pathways in different global environmental assessment studies.**

Arrows indicate links in the analyses from environmental conditions (left) to food security outcomes (right).
Source: Wood *et al.* (2010).

system, in particular how natural and socioeconomic system components interact.

Water security

Regular access to clean water is a growing concern across multiple regions of the world, affecting two-thirds of the population (see 4.3.2.1). Water scarcity is strongly driven by behaviour driving overconsumption, infrastructure, and climate change. Climate projections indicate that a global temperature increase of 3-4°C could cause altered run-off patterns and glacial melt that will force an additional 1.8 billion people to live in a water scarce environment by 2080 (UNDP, 2007). Other drivers such as rising populations in flood-prone lands, climate change, deforestation, loss of wetlands and rising sea levels are expected to increase the number of people vulnerable to floods to 2 billion in 2050 (WWAP, 2012). Drylands are particularly vulnerable to changes in rainfall (Carpenter *et al.*, 2006), and with climate change, drought impacts are anticipated to intensify across increasing extents of the world's drylands (IPCC, 2013). The world's megacities are already facing increasingly frequent and acute water shortages, which can be expected to worsen in the future (Li et al 2015a). Similarly, in coastal regions, decreases in precipitation and fresh water supplies, along with projected increases in sea level, sea surface and air temperatures, and ocean acidification are projected to have major negative effects on water security for societies (McMillen *et al.*, 2014). The 'fresh water planetary boundary' is approaching rapidly (Dearing *et al.*, 2014; Rockström *et al.*, 2009), and sustainability of water use will likely be difficult to achieve in the near future (Gosling & Arnell, 2016). According to the results of the systematic literature review, water security indicators show negative trends in global and continental scale scenarios **(Figure 4.4.3)**.

Energy security

Ensuring the global population's access to modern and sustainable energy services in consideration of environmental integrity remains a major challenge for policymakers and practitioners worldwide. According to the systematic literature review, energy security derived from nature appears to be the only indicator with no identified negative trends in global scale scenarios **(Figure 4.4.3)**. However, scenarios such as decarbonisation ones, appear to also provide other benefits in addition such as lower energy market risks (Jewell *et al.*, 2014). However, energy security faces several other challenges. Energy security has both producer and consumer aspects (UNDP, 2004). Access to sustainable energy, which can include bioenergy sources, is critical in enabling people to meet essential needs linked with good quality of life as energy security encompasses availability, affordability, efficiency and environmental acceptability. The development of energy models in the 1970s in response to the energy crisis has provided relevant insights into the consumption and management patterns towards a sustainable energy for all future. On the other hand, current uneven global consumption coupled with the dearth of studies and quantitative data on energy use, especially from developing economies, presents a challenge for developing effective forecasting models. Scenarios based on non-linear energy consumption consider limiting overconsumption can keep 2040 energy consumption at 2010 levels, while increasing energy-for-life efficiency can keep 2040 energy use at 2010 levels (Pasten & Santamarina, 2012).

Livelihood and income security

While global scenarios lack sufficient attention to livelihood impacts, the results of the systematic literature review indicate regionally differentiated negative trends projected for livelihood and income security in the future **(Figure 4.4.3)**. Employment and incomes derived from nature are indicative for value derived in cash or direct use that impact good quality of life. Nature-based income, as part of environmental income, includes that derived from resources such as fish, timber, and non-timber forest products such as fuel wood, game, medicinals, fruits and other foods, and materials for handicrafts or art. It also includes income from nature-based tourism, as well as payments that rural landowners might receive for environmental services such as carbon storage or preservation of watershed functions. Also included is income from aquaculture as well as from small-scale agriculture, including commodity crops, home gardens, and large and small livestock. Nature-based livelihoods may become precarious with intensifying future trends in environmental change and its drivers (Hopping *et al.*, 2016). Climate change-induced depletion of household assets may have especially negative impacts on the future welfare of populations already fighting poverty. For example, farmers in Sub-Saharan Africa will spend an increasingly high share of their income on securing basic needs such as food, while housing and related needs also intensify (Enfors & Gordon, 2008).

Health

The future of biodiversity and ecosystem services is inextricably linked to that of human health and well-being, for instance, through supporting healthy diets to mitigating the health impacts of climate impacts or pollution. Many health benefits are related to the conservation or use of specific elements of biodiversity such as species or genetic resources. Indigenous communities increasingly anticipate, and are impacted by, changes to traditional practices and pathways of food, toxicity impacts from distant (e.g., pesticides) and local (e.g. mining) sources, hunting and gathering of medicinal plants, and experience their consequences for local diets and resistance to diseases, as exemplified in Queensland Australia (McIntyre-Tamwoy *et al.*, 2013), by Arctic Bay Inuit (Ford *et al.*, 2006), and across North American and Russian indigenous populations. As

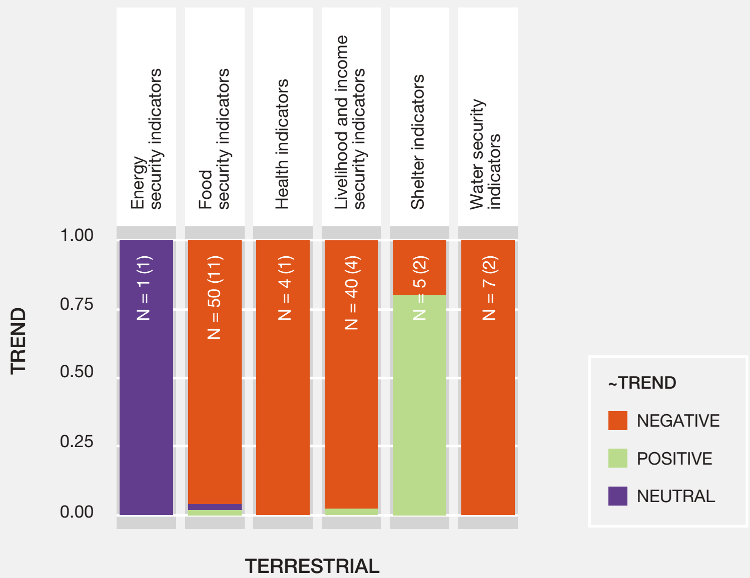


Figure 4 4 3 **Trends in selected indicators of GQL in terrestrial ecosystems. Colors indicate the value trend of the indicator.**

"N" indicates the number of results reported per facet, with the number of papers indicated in parentheses.

environmental hazards and extreme weather events increase in frequency, intensity or duration, they are expected to have increasingly visible consequences for health (Bai *et al.*, 2016).

Projected increases in the production of biofuel crops, in particular in case of woody bioenergy species (eucalypt, poplar) which emit more isoprene than traditional crops, suggest important impacts on ground-level ozone concentrations, and consequently on human health and mortality (Ashworth *et al.*, 2013). On the other hand, projected reductions of anthropogenic air pollutants point towards a widespread decline of small aerosol particles; projected future wildfires may not alter this general trend except for some parts of the wildfire season (Knorr *et al.*, 2017). Projected environmental changes are also expected to impact the prevalence of vector borne diseases such as malaria. Of the four MA scenarios, health under the "techno garden" scenario was expected to ameliorate due to technological advancements (Butler & Oluoch-Kosura, 2006; Carpenter *et al.*, 2006). Likewise, climate change under the five shared socio-economic pathways affects health outcomes (Ebi, 2014). Some health indicators can be expected to decline according to the systematic literature review **(Figure 4.4.3)**, however, more comprehensive global scenarios need to address various dimensions of health impacts.

4.4.1.1.2 Non-material dimensions of good quality of life

Along with material needs, human well-being depends profoundly on non-material and experiential factors (Butler & Oluoch-Kosura, 2006). However, narratives around good quality of life in global scenarios typically ignore such non-material dimensions which include but are not limited to: social relations, equity, cultural identity, values, security, recreation, knowledge and education, spirituality and religion, and freedom of choice and action.

Good social relations

Social relations refer to the degree of influence, respect, co-operation, and conflict that exists between individuals and groups (MA, 2005). Good social relations underlie the development of strong institutions and collective action, providing routes for sustainable use and management of nature and nature's contribution to people. The natural environment has important influences not only on individual well-being, but social relations as well (Hartig *et al.*, 2014). Good social relations also include mutual respect, social cohesion, and good gender and family relations. The linkages between good quality of life, nature and nature's contribution to people were explicitly identified in the Millennium Ecosystem Assessment, with an emphasis on cultural and spiritual values (MA, 2005). Even though the world is more connected than ever before, social differentiation remains a major constraint to social relations at multiple scales and in many cases is closely associated with inequality in access to nature and natural resources. Thus, it is crucial to address disparities among stakeholders in and across socio-ecological systems and the role of social relations in negotiating such disparities, in order to more fairly and equitably address how nature and NCP can be leveraged to promote a good quality of life. The degradation of ecosystems, highly valued for their aesthetic, recreational, or spiritual benefits, can also damage social relations, by introducing or exacerbating disparities among social groups and reducing the bonding value of shared experience, including resentment towards and resistance against groups that disproportionately profit from their damage. While global scenarios of future trends in social relations are elusive, climate and land-use changes in the future are highly likely to accentuate social inequity in use of and access to resources, in the absence of changes in governance arrangements to address current disparities.

Equity

Equity broadly concerns an even distribution of nature's contributions to people, and access to natural resources and rights (see also section 4.4.3). Typically three dimensions of equity are considered: (1) distribution, (2) procedure, and (3) context, access and power (McDermott *et al.*, 2013). Equity concerns evidence of parity in processes and outcomes across gender, age, race and ethnicity, income and other social indicators or axes of difference. It is fundamental to human rights, including the rights of IPLCs (see also **Box 4.4.1**), and implicitly influence nature, its contributions to people and good quality of life (Breslow *et al.*, 2016). Equity addresses fairness or justice in the way people are treated. In principle, equity concerns pertain to at least three domains –international, intra-country, and inter-generational. Social justice (equity) constitutes one of the three pillars of sustainable development, along with economic prosperity (development) and ecological integrity (sustainability) (Banuri *et al.*, 2001). Equity may increase in scenarios where the consumption of material goods is reduced relative to that of services and intangibles, such as the new welfare scenario (Sessa & Ricci, 2014). Equity is also expected to increase in global sustainable development scenarios such as SSP1, B1 (A1T), B2, sustainability first, global orchestration and techno garden, and some economic optimism scenarios such as SSP5. In regional competition scenarios such as SSP3/4, A2, security first and order from strength, equity is expected to be low (see section 4.1).

Cultural identity

Cultural identity includes concerns related to the terms, language, activities and practices that embody the relationships of people and nature. The cultural identity of IPLCs is particularly linked to long-term material and non-material relationships to nature and place, with direct and sustained physical and experiential interactions (e.g., see section 4.3.2.3 above). As indicated earlier, among the direct and indirect drivers of changes to such interactions, and to fundamental aspects of IPLCs cultural identity, are urbanization, climate change, demographic changes, technology, psycho-social or cultural factors, and health and development. Future threats to biodiversity and ecosystem services also constitute imminent challenges to the cultural identity of communities, particularly when faced with environmental degradation. For example, "blue-ice," as a term inherent to First Nation languages and as the material formation on lakes and rivers, links transportation to access to food and energy. It is thus central to First Nations' cultural identity and traditional activities, and their future well-being (Golden *et al.*, 2015). Such relations are at once material and symbolic. As section 4.3.2.3 also highlights, symbolic meaning is intimately tied to spiritual, religious and cultural identity, and strongly shapes social cohesion, and future trends in these relations are central to IPLC futures.

Personal and physical security

Future climate change poses physical risks with implications for human safety and security. Such risks emanate from multiple dimensions, including those linked to increased exposure to episodic stress (e.g., extreme climate events) as well as chronic pressures (e.g. related to warming temperatures and sea level change). For instance, climate change scenarios in the Great Barrier Reef indicate marked declines in security that accompany declines in ecosystem services, along with indicators of equity, education, health and shelter (Bohensky *et al.*, 2011a). In other examples, projections of future population dynamics have indicated that more people may live in areas that are prone to both floods and wildfires in the future (Knorr *et al.*, 2016). In northern regions, among other risks, for some populations, traveling on thinning ice in winter is becoming more dangerous, restricting movement of people and goods (Ford *et al.*, 2006).

Recreation and leisure

There is considerable research from environmental psychology on the human health and well-being benefits from recreation in nature (Barton & Pretty, 2010; Marselle *et al.*, 2014). The Millennium Assessment Technogarden scenario (see section 4.1) argues for the multifunctionality of land-use including recreational opportunities, seen as an affordable luxury in e.g., the Order from Strength scenario (MA, 2005; see also Appendix 4.4). Similarly, the SRES B1 (A1T) mentions the preservation of recreational spaces (Nakicenovic *et al.*, 2000; see also Appendix 4.4). Loss of coral reefs under the RCP2.6 and RCP8.5 scenarios (section 4.2.2.2.2) could cost between U.S. $1.9 billion and U.S. $12 billion in lost tourism revenues per year, respectively (Gattuso *et al.*, 2015). The loss of recreational areas such as camping sites is signaled as a regional concern by indigenous participants in case studies in Australia (McIntyre-Tamwoy *et al.*, 2013).

Knowledge and Education

Knowledge and education related to biodiversity and ecosystem services are essential for ensuring good quality of life. The taxonomic records of world fauna and flora indicate 8.7 million known species (Mora *et al.*, 2011), which represent only a fraction of the species that may exist (WRI *et al.*, 1992), indicating a large knowledge gap on fundamental aspects of biodiversity. It has been estimated that 86% of existing species on Earth and 91% of species in the ocean still await description (Mora *et al.*, 2011). Much of the knowledge used in scenarios of biodiversity and ecosystem services is derived from biology, ecology and related disciplines.

Yet, a variety of conceptualizations of biodiversity are embedded in local knowledge and cultural memories directly relevant to regional and global resource and food production systems (Nazarea, 2006), but poorly represented in future scenarios. Additional perspectives could be derived from work on human cognition, decision-making, and behavior. For example, ethnobiology of agricultural diversity, cultural ecology of plant genetic resources, participatory conservation, politics of genetic resources, and legal dimensions of biodiversity conservation are very poorly represented in scenario development. The role of education has been to some extent explored in global scenarios. Specifically, the narratives of scenarios SSP1 and SSP5 assume that the human capital component of education is highest compared to SSP2, SSP3 and SSP4 (KC & Lutz, 2017). Schools play an important role in educating pupils and students to be active and responsible towards the environment, and the challenge of biodiversity conservation (Torkar, 2016; Ulbrich *et al.*, 2010).

Spirituality, religion

A number of studies highlight the ways in which spirituality is related to good quality of life. Spirituality has been considered in a variety of ways, ranging from the traditional understandings of spirituality as an expression of religiosity in search of the sacred, to humanistic views of spirituality not specifically anchored in religion, or at least, ecclesiastical religion. Fisher (2011) noted that the spiritual health of individuals has four important domains: personal, communal, environmental and transcendental. Many religions emphasize a deep connection or oneness with nature, including Hinduism, Buddhism, Jainism, Christianity and Islam. For example, in India, patches of forest frequently constitute sacred groves of varying sizes, which are communally protected with significant spiritual connotations.

The rapid retreat of the Gangotri Glacier, the sacred source of the Ganges, is alarming for Hindu religious practitioners (Verschuuren *et al.*, 2010). The landscape that surrounds sacred groves has a vital influence on biodiversity within them (Bhagwat *et al.*, 2005). Similarly, sacred sites in Italy often display ecological features that highlight their important conservation role (Frascaroli, 2013). These sacred places are, symbolically, repositories of knowledge of our planet as 'home.' Our relationship with nature and GQL, where the spirit of nature and culture meet, and are additionally memorialized and maintained by rituals and festivities performed there. However, most of the current archetype scenarios of biodiversity and ecosystem services fail to incorporate the spiritual and cultural significance of nature.

Freedom of choice and action

Freedom emphasizes a person's social, political, economic, and personal rights, and whether one is actually able to exercise these rights. Freedom of choice and action is a vital pre-requisite to GQL. In practical terms, freedom can promote or inhibit access to nature and its multiple benefits needed to sustain life. Human and natural constraints prevent different groups of people around the world from having or exercising freedom of choice and action to access nature and its benefits needed for good quality of life. Thus, even though nature and its contributions to good quality of life may be abundant in certain areas, lack of freedom may impede access. Projected changes to climate, biodiversity and ecosystem services can be expected to directly impact social access to nature and its benefits. In addition, future changes can strongly impact the institutions shaping freedom and choice. For instance, experience has shown that sociopolitical institutions and environmental regulatory regimes tend to favour certain groups over others. In the Doñana protected area from Southern Spain, freedom of action and choice is completely reduced in a future scenario of market liberalization (Palomo *et al.*, 2011). Similar trade-offs with GQL are evident in the varying degrees of environmental protections at the global scale. For instance, different IUCN categories in protected areas, from the most stringent preservationist approaches excluding human use, to the more integrated protection categories incorporating some (sustainable) use, have vastly different implications for GQL in different communities living in those regions.

4.4.1.2 Good quality of life across worldviews and knowledge systems

GQL conceptualizations across worldviews and knowledge systems vary considerably due in part to values, beliefs and worldviews, as well as social and political contexts. What GQL entails is highly dependent on place, time and culture, with different societies espousing different views of their relationships with nature and placing varying emphasis on collective versus individual rights, or the material versus the spiritual domain. Understanding and appreciating plausible GQL scenarios require an integrative assessment of subjective and objective approaches and indicators for quality of life, including quantitative or qualitative social and economic measures (Cummins *et al.*, 2003; Diener *et al.*, 1999; Easterlin, 2003; Haas, 1999). Over the past half century, increasing research and policy attention has been directed to socio-ecological concerns relevant to Indigenous People and Local Communities (IPLCs) (e.g., **Box 4.4.1**), with recognition of long histories and ongoing processes of exclusion and marginalization of IPLCs in ecosystem and biodiversity conservation and management across socio-ecological regions. The IPBES framework acknowledges the varying perspectives of GQL across knowledge systems, cultures and societies (Díaz *et al.*, 2015).

While indigenous worldviews differ from one community to another, indigenous understandings of well-being are also frequently intertwined with understandings of nature; the relationship between people and their environment happens not only at a cognitive level. In many societies, "prestige and satisfaction are gained through relationships and generosity rather than in accumulation of personal wealth. A good life is one spent in service to one's community, in living in balance with the other lifeforms of one's homeplace. Responsibilities extend not just to the present, but to many generations into the future" (Turner & Clifton, 2009). Different understandings also exist around the notion of 'time'. In Iñupiaq and Siberian Yupik culture, for instance, it is important for hunters to avoid speculating about the future, reflecting the belief that one should be humble about one's abilities to predict it, and not expect any one particular outcome over another (Voorhees *et al.*, 2014). Addressing quality of life under different plausible futures will benefit from bridging indigenous and local epistemologies with scientific knowledge systems (Tengö *et al.*, 2017), such as initiatives addressing mitigation and adaptation from a local perspective (UNU-IAS & IGES, 2015).

4.4.2 Linking good quality of life to nature and nature's contributions to people across future scenarios

4.4.2.1 Mediating factors of future GQL and NCP

Future quality of life and its relation to nature and its contributions to Ppeople (NCP) is expected to be mediated by a bundle of overlapping factors across socio-ecological systems at local and global levels, from the individual or the household to the system **(Figure 4.4 4)**. These mediating factors are fundamental to shaping the productive base of a society, including substitutable capital assets, i.e. natural,

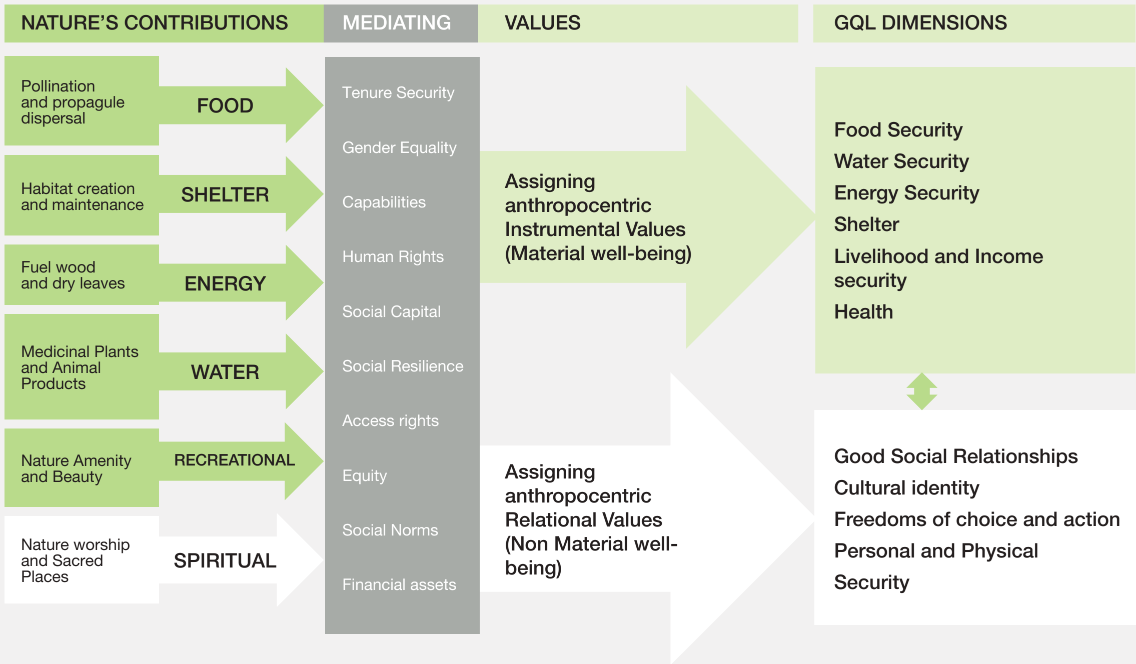


Figure 4 4 4 **Conceptual model of mediated relationships between nature's contributions to people and good quality of life (GQL).**

produced, and human capital (Duraiappah *et al.*, 2014). They are akin to indirect drivers of changes to nature, NCP and GQL, and include tenure security (e.g., use and access rights), equity concerns, power relations, formal and informal institutions and human rights, technology access, financial assets, and social capital and social resilience (Horcea-Milcu, 2015; Shapiro & Báldi, 2014; Spangenberg *et al.*, 2014). However, inequities, political challenges and distributional issues are seldom discussed by scenarios considering implications for GQL.

Social groups have distinct ways to derive well-being from NCP, as a result of a range of interlinked mediating factors (Horcea-Milcu, 2015). For example, policies such as the European Common Agriculture Policy rural development program of agri-environment schemes may increase nature's contributions to people, but because it does not holistically engage with mediating factors it will not equitably increase access to benefits (Horcea-Milcu, 2015). Although people's values and attitudes are crucial in shaping the future, they are rarely central to scenario exercises. Novel methods, such as the three horizons approach (Sharpe *et al.*, 2016) have been developed to fully integrate people's worldviews into scenario planning, however transcendental values held by the social groups are only beginning to be considered (Kass *et al.*, 2011). For example, the ethnographic futures framework focuses on how changes in the natural environment take place through human agency and how society will act as recipient in the future (Kass *et al.*, 2011). Importantly, the process of elaborating scenarios is increasingly taking into account participatory approaches and corresponding value negotiations around the meaning of good quality of life. Consequently, ethical questions emerge regarding how to build scenarios so that local knowledge and IPLCs are not coopted in ways that may exacerbate processes of their social marginalization (but see also **Box 4.4.1**).

How mediating factors may be expected to change in magnitude and direction across different archetype scenarios remains to be explored. Scenarios of regional sustainability seem more suited for mitigating the negative influence of mediating factors (Hanspach *et al.*, 2014). Mismatches among mediating factors, nature and NCP may pose challenges. For instance, Duraiappah *et al.* (2014) identified mismatches of individuals' values (e.g., of ecosystem services within different social contexts), mis-matches in ecosystem services and ecosystem scales (at which levels of biodiversity, ecosystem processes and functions operate to produce the bundle of provisioning, regulating, and cultural services), and mis-matches of institutions (those that account for spatial, temporal, and functional fit in managing ecosystem services).

The way NCP components will be filtered and transformed to GQL components and reach beneficiaries such as individual, social groups or societies will be highly influenced by mediating factors such as: access arrangements, assets, institutions, values and norms. One avenue to incorporate this variability is integrating more participatory, deliberative or transdisciplinary processes into scenario building endeavors towards improved considerations of GQL in its variety of components, whether material or non-material, of local or global concerns. Storylines of socio-economic development used in global scenarios include few indicators of GQL, typically predicated on its material aspects. Given these limitations, lessons learnt from the current assessment is that indicators of GQL in global scenarios generally improve in the future in the "global sustainability", "regional sustainability", and "economic optimism" scenario archetypes. However, continued degradation of nature and non-provisioning NCP in the "Economic optimism" scenarios suggests that the decoupling of GQL from Nature and non-provisioning NCP that is often currently observed could potentially continue into the future. Indicators of GQL have the poorest future trajectories in the "regional competition" scenarios and do only slightly better in "business-as-usual" scenarios at the global scale.

4.4.2.2 Future scenarios of GQL and NCP

Key characteristics of GQL indicators are assumed to substantially improve in the future with a reduction in global poverty in the "global sustainability" archetype and to a lesser extent in the "regional sustainability," but with recognizable regional differentiation (section 4.1). These improvements in GQL in sustainability scenarios go hand-in-hand with the most favorable projections of future dynamics of nature and NCP. However, continued degradation of nature, especially in developing economies of the tropics, and the consequences on NCP in the "economic optimism" scenarios suggest that the decoupling of economic growth on the one hand and nature, NCP and GQL on the other hand (see Chapters 2 & 3, and sections 4.2.2-4.2.4) could potentially continue into the future.

Indicators of GQL (Table A4.4.1, Appendix 4.4) have the poorest future trajectories in the "regional competition" scenarios and do only slightly better in "business-as-usual" and "economic optimism" scenarios at the global scale with substantial geographical differentiation. One of the underlying components of these storylines (particularly in the regional competition archetypes) is fragmentation, and large geographical variation in indicators of GQL. These scenarios also lead to the least optimistic future projections of nature and NCP (sections 4.2 & 4.3). These scenarios suggest that many of the current trends in socio-economic development (see Chapters 2 & 3) are projected to lead to lose-lose-lose responses of nature, NCP and GQL in the future (section 4.5) with inhabitants of developing economies expected to be severely impacted.

The literature review also finds that plausible scenarios are more likely to recognize the importance of nature for fulfilling material dimensions rather than the non-material ones. Similarly, there is a gap in the literature on the extent to which GQL dimensions depend on nature's contributions, and how they fit together. The literature clearly documents a strong correlation between nature's contributions and good quality of life (**Figure 4.5.2b** in section 4.5). Notably, positive trends in NCP are correlated with corresponding positive trends on GQL (top right of **Figure 4.5.2b**). Negative trends in NCP and GQL are similarly correlated (bottom left of **Figure 4.5.2b**) and comprise the bulk of the correlations reported as scenarios' outcomes. Nevertheless, analyses of such NCP-GQL relations could be further specified for scenarios exploring how those relations are mediated by contextual factors. For instance, future scenarios voiced by Amazonian communities reveal concerns with regard to livelihoods, equity aspects and the long-term impacts for communities and nature (Evans & Cole, 2014).

A challenge to the assessment of NCP and GQL under different future scenarios is their socially differentiated nature. This means that different groups may experience changes in NCP differently and with distinct impacts on GQL, so that a given change scenario usually implies winners and losers. People vary in their access to ecosystem services, exposure to disservices, dependence on ecosystems, and needs and aspirations for NCP. These are influenced by societal structures and norms as individual characteristics (Daw *et al.*, 2011) and power relations (Berbés-Blázquez *et al.*, 2017; Horcea-Milcu, 2015). Access shapes the transformation of ecosystem services to human well-being. For example, the perception of, dependence on and access to ecosystem services are strongly gendered. Men and women participate in different ecosystem-based livelihoods due to gendered roles and responsibilities gendered access to physical space, and gendered knowledge systems about ecosystems and NCP.

Thus, decision-making about environmental management with implications for different bundles of ecosystem services is an intently political process, with different stakeholders favouring different outcomes and holding different levels of power within those processes (Schoon *et al.*, 2015). Value systems and societal preferences for example evolve through globalisation of culture, or from burgeoning environmental consciousness in society (Everard *et al.*, 2016). Thus, changes in NCP and GQL are affected by social, economic, institutional change as well as biophysical change. Also how GQL of particular groups of people will respond to changes in biophysical conditions will be influenced by a wide range of factors (Daw *et al.*, 2016); see also section 4.4.2).

Evaluating GQL under different scenarios of change can benefit from deliberative and participatory approaches that consider a wide range of stakeholder views, and disciplinary perspectives (e.g., Brand *et al.*, 2013). Such a diversity of perspectives is necessary to take account of the multiple interacting factors and socially differentiated experiences, vulnerabilities and preferences for NCP (Barnaud *et al.*, 2018) as well as complexity and uncertainties in how NCPs evolve (Lele & Srinivasan, 2013).

Narrowly informed assessments of change may overlook socially differentiated outcomes. For example, aggregate analysis of a small-scale fishery in Kenya showed a win-win opportunity to improve profitability and conservation outcomes by reducing fishing effort and the use of small meshed beach seine nets. However, an inclusive participatory modelling approach showed that the livelihoods of certain groups, such as women traders would be negatively impacted by such a change due to the gendered nature of the value chain (Daw *et al.*, 2015). Likewise, in southern India, a disaggregated economic analysis shows how different stakeholder groups would experience different benefits and costs from the implementation of a forest conservation area (Lele & Srinivasan, 2013). For example, non-indigenous groups would suffer from curtailment of firewood and grazing benefits while indigenous groups would also lose out on these services but benefit to a greater extent from increased opportunities and sale of non-timber forest products. Importantly, from the perspective of developing scenarios, these wins and losses are shown to be highly contingent on complex institutional, technical and ecological dynamics in terms of access arrangements, irrigation methods and invasive species, respectively (Lele & Srinivasan, 2013).

Trade-offs between the good qualities of life of particular societal groups might easily be overlooked due to the complexity of ecological and social relationships, because the 'losers' of such trade-offs are marginalised or lack a voice in assessment processes and because of the psychological and political biases towards 'win-win' narratives that overlook uncomfortable or inconvenient trade offs (Daw *et al.*, 2015). A limitation with participatory approaches is the difficulty of imagining future scenarios of changes in the 'demand side' of NCP. So, a group may discuss how changes in a resource might be affected by climate change, but it is often framed in terms of current social conditions. Social, economic and political changes can have major impacts on NCP and subsequent effects on GQL.

Perspectives on GQL are also disputed and dynamic amongst modern and urban populations in wealthy countries. Increasing interest in well-being by Western governments (e.g., the OECD better life index http://www.oecdbetterlifeindex.org/) is critical for future scenarios because development trajectories, informed by the pursuit of economic growth are a major driver of ecosystem change. The possibility of a broader conceptualisation of well-being informing economic and development policy could have a major impact on the drivers behind environmental change.

Different conceptualisations or subjective experiences of GQL extend into relationships with ecosystems. While dominant economic framings in modern societies have emphasised instrumental values of nature, spiritual and aesthetic-cultural

Box 4 4 1 Climate Futures and Rural Livelihood Adaptation in Nusa Tenggara Barat, Indonesia.

What different futures are plausible for Indigenous People and Local Communities (IPLCs)?

Nusa Tenggara Barat (NTB) Province in the island archipelago of Eastern Indonesia is one of the country's poorest regions, and highly vulnerable to climate change due to dependence on rural, ecosystem-based livelihoods (Kirono *et al.*, 2016). It is therefore representative of other island regions in the tropical Asia-Pacific, which share the challenges associated with rapid change and entrenched poverty intertwined with complex traditional culture (Butler *et al.*, 2014, 2016a).

To assist communities to navigate future changes, from 2010-14, the Australian Government funded a series of scenario planning workshops with multiple stakeholders to investigate alternative development pathways and potential impacts on ecosystem services (Butler *et al.*, 2015). The project's Theory of Change assumed three evolutionary stages of adaptive co-management that would be triggered: 1) capacity building, 2) policy and program development and 3) implementation, adoption and scaling out. A participatory evaluation was carried out to test these assumptions and measure outcomes (Butler *et al.*, 2016c).

A key principle of the scenario planning process is that multiple stakeholders must be engaged through collaborative learning and knowledge co-production (Butler *et al.*, 2016c). Scientific and local knowledge was integrated in an interactive and iterative process throughout the workshops with the goal of co-producing knowledge via a 'learning spiral' **(Figure 4.4.5)**. Stage 1 scenario workshops were carried out with provincial level stakeholders, and then repeated in Stage 2 for five sub-districts and their community level stakeholders; Stage 3 then integrated the outputs of Stages 1 and 2 **(Figure 4.4.5)**. Stages 1 and 2 were structured around four questions: 1) What are the drivers of change for livelihoods? 2) What is the desired future for livelihoods? 3) What are the possible futures for livelihoods? and 4) What are the priority 'no regrets' adaptation strategies required to achieve the desired future in spite of future uncertainty?

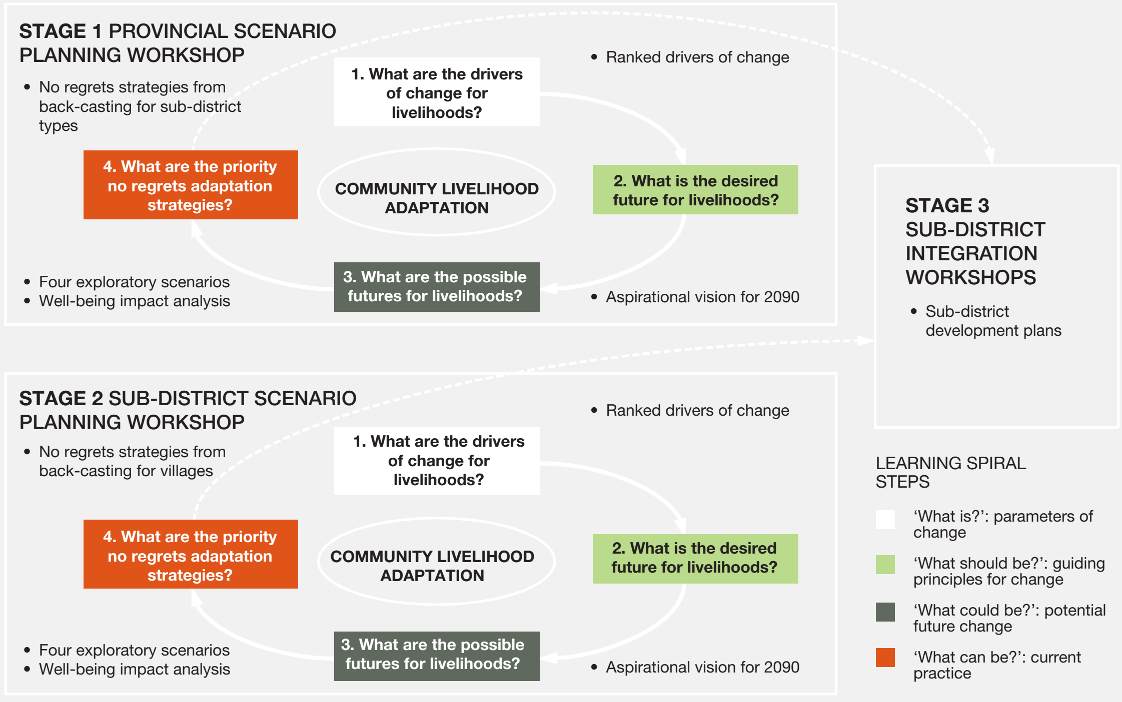


Figure 4 4 5 **Stage 1 and 2 scenario planning workshop steps and primary outputs (bullets) based on Brown's (2008) learning spiral.**

Also shown are the links to the subsequent Stage 3 sub-district integration workshops. From Butler *et al.* (2016b).

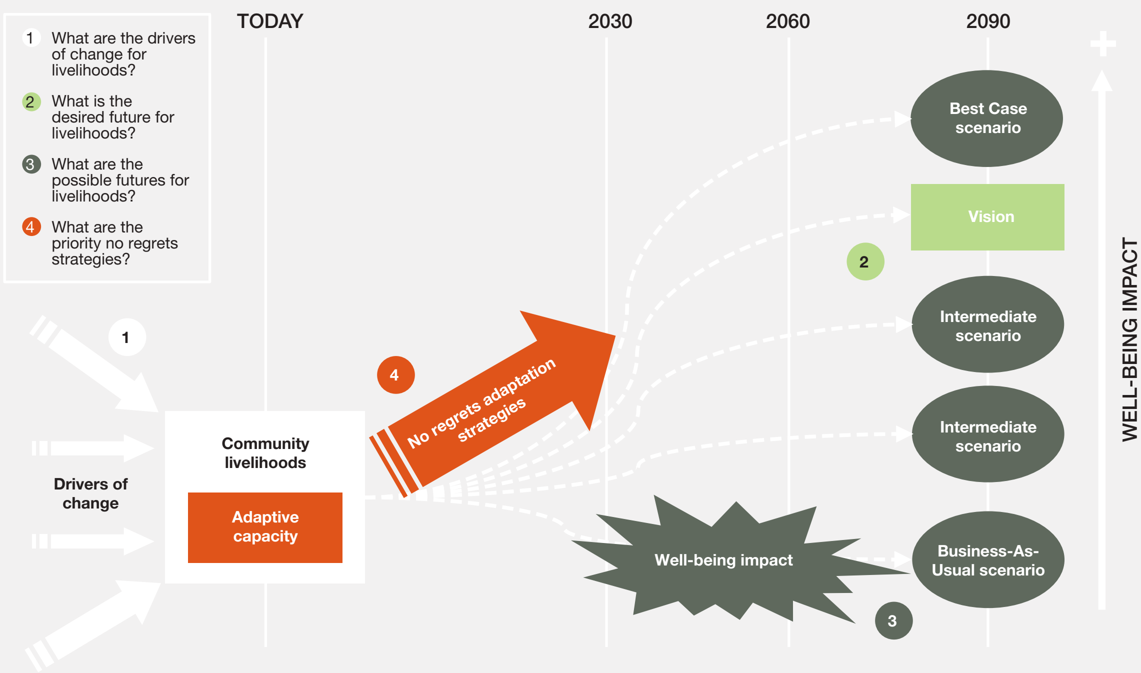


Figure 4 4 6 **The 'roadmap' used in the Stage 1 and 2 scenario planning workshops to explain the sequential learning steps.**

The step numbers and questions correspond to the learning spiral in Figure 4.4.5. From Butler *et al.* (2016b).

Participants in Stage 1 identified two key drivers from a list of 50 current drivers of change: development of human resources and climate change. They described a desired future vision for NTB rural livelihoods in 2090 based on adequate income, health, food security, social cohesion and freedom of choice for a good life. A matrix of four possible future scenarios was created from better or worse extremes of human resources development and climate change. Participants created narratives and illustrations for each scenario **(Figure 4.4.7)**.

An ecosystem goods and services typology and model was used to project future ecosystem goods and services and impacts on human well-being in 2030 for the business-as-usual scenario **(Figure 4.4.6)**. The most affected ecosystem types were rice and bandeng (fish) ponds, diverse cropping and coastal activity, diverse agriculture and forest use, and rice and tobacco (Skewes *et al.*, 2016). However, communities dependent on these ecosystem types for their livelihoods have varying levels of adaptive capacity. Hence, an adaptive capacity index was developed to rank vulnerability of NTB livelihoods, which identified the diverse cropping and coastal activity livelihood as most vulnerable. This assessment helped the participants to select sub-districts for community case studies in the next phase. Based on ecosystem goods and services and human well-being impacts and adaptive capacity for each typology, participants designed adaptation strategies for livelihoods to steer them away from 'business-as-usual' towards the NTB vision and the 'Best Case' Well-being Village scenario.

The same process was undertaken for each case study sub-district in the Stage 2 workshops, with more focus on local issues, knowledge and ecosystem goods and services.

Through the process, surveys identified distinct 'knowledge cultures' amongst stakeholder types in this region (e.g. government, communities and NGOs), with differing perceptions of future time horizons, climate change and development priorities (Bohensky *et al.*, 2016; Butler *et al.*, 2015). This finding justified the project design, which intentionally carried out the process at multiple scales in Stages 1 and 2, and then finally integrated the results by bringing stakeholders representing different scales together in Stage 3 (Figure 4.4.5). As a consequence, learning and innovation was one of the primary outcomes of the process (Butler *et al.*, 2016c).

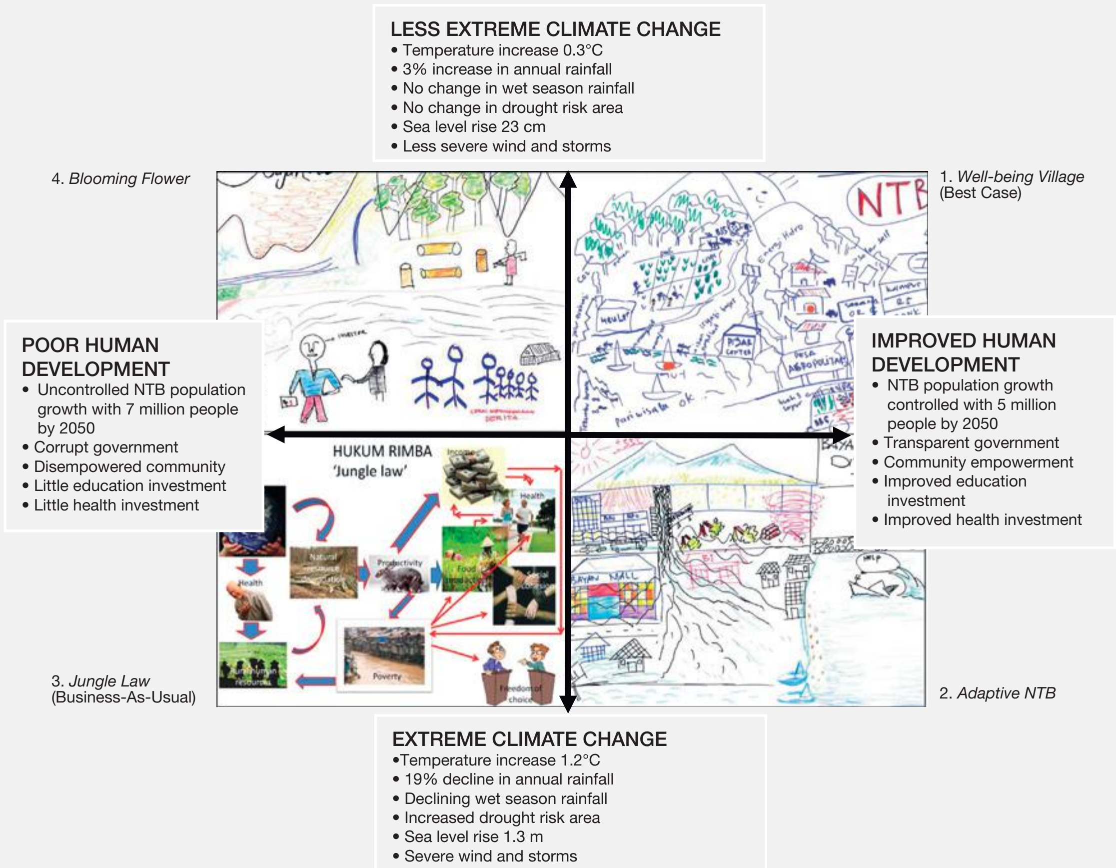


Figure 4.4.7 **Driver themes, sub-themes and exploratory scenarios for 2090 from the Stage 1 provincial workshop.**

From Butler *et al.* (2016b).

How indigenous and local knowledge (ILK) can be integrated with scientific knowledge in scenario-based projects towards Sustainable Development Goals (SDGs)

Participatory scenario planning has become a popular tool for navigating changes faced by many Indigenous Peoples and Local Communities. Integrating knowledge and multiple perspectives on change drivers, how the future might look and how stakeholders might respond, can potentially catalyse single-, double- and triple-loop learning that enable adaptation (Butler *et al.*, 2016c; Totin *et al.*, 2018).

The power of scenario planning to effect real change may be limited, however. While such scenarios present local visions for alternative futures in ways that conventional models, projections and forecasts cannot (Peterson *et al.*, 2003; Wollenberg *et al.*, 2000), their widespread adoption has not been matched by adequate resources. A review of place-based participatory scenarios found that very few projects complete a rigorous evaluation of outcomes (Oteros-Rozas *et al.*, 2015). Even in well-funded, multi-year projects such as the project in NTB, scenarios have only catalysed partial learning and change (Butler *et al.*, 2016a). In particular, the adoption of incremental rather than transformative adaptation strategies suggest that root causes of community vulnerability were not fully acknowledged, although numerous systemic drivers were identified. Scenario planning should be considered as only one tool in a process of capacity-building. This is particularly important in developing country contexts where capacity of stakeholders is low (Chaudhury *et al.*, 2013; Vervoort *et al.*, 2014). One-off scenario planning can generate enhanced learning and social networks but is unlikely to create transformational change needed to address systemic issues such as politics and institutions (Totin *et al.*, 2018). Ideally, the principles of futures analysis and learning should also be integrated within existing decision-making or development planning processes (Butler *et al.*, 2016c). If sustained, such grassroots platforms may catalyse and implement transformation, and ultimately enable vulnerable communities to leap-frog the SDGs (Butler *et al.*, 2016b).

values, whether of indigenous or modern societies, are hard to capture by instrumental thinking that underlies economic ecosystem service approaches. Instead, they are grounded in conceptions of nature that differ from the ecosystem services conceptual framework (Cooper *et al.*, 2016).

4.5 TRADE-OFFS, CO-BENEFITS AND FEEDBACKS BETWEEN NATURE, NATURE'S CONTRIBUTIONS TO PEOPLE AND GOOD QUALITY OF LIFE

4.5.1 Analysis of interactions from the Systematic Literature Review

Very few models and scenarios have been developed that simulate the complex interactions between nature, nature's contributions to people and good quality of life at continental or global scales, although such interactions are qualitatively well described and documented in the literature. As a result, scenario outcomes developed so far do not cover the full range of plausible futures. In the systematic literature review conducted for this chapter (Appendix A4.1.1), only 14 papers (out of a total of 572 papers), reporting a total of 41 different scenarios outcomes, addressed interactions between nature and NCP and GQL **(Figure 4.5.1)**. Advancing scientific knowledge about such interactions is crucial because of their relevance for identifying feedback effects, understanding trade-offs or win-win solutions and the risk of breaching thresholds and so–called "tipping points".

Analyses of the systematic literature review **(Figure 4.5.2)** suggest further that while relationships between nature, NCP and GQL are both positive and negative, the reported results indicate that the majority of indicators' trends are correlated either positive-positive or negative-negative. For instance, if a trend in a nature indicator is positive, there is more chance that a trend in an associated NCP is also positive **(Figure 4.5.2a)**, and conversely for negative/negative relationships. 62% of the simulated interactions between nature and NCP indicators' trends are correlated that way (excluding cases where both indicators of Nature and NCP have null trends). Likewise, the majority of relationships between NCP and GQL are positive-positive or negative-negative (80%; **Figure 4.5.2b**). The high proportion of such correlations suggests the existence of opportunities and potential co-benefits of measures aimed at preserving a specific nature's component, or a specific ecosystem service (section 4.5.3). However, the literature analysis does not allow to decipher whether there are causal relationships behind the positive correlations, and whether there are differences across regions or changes in trend over time (near vs. longer-term future). In addition, the level

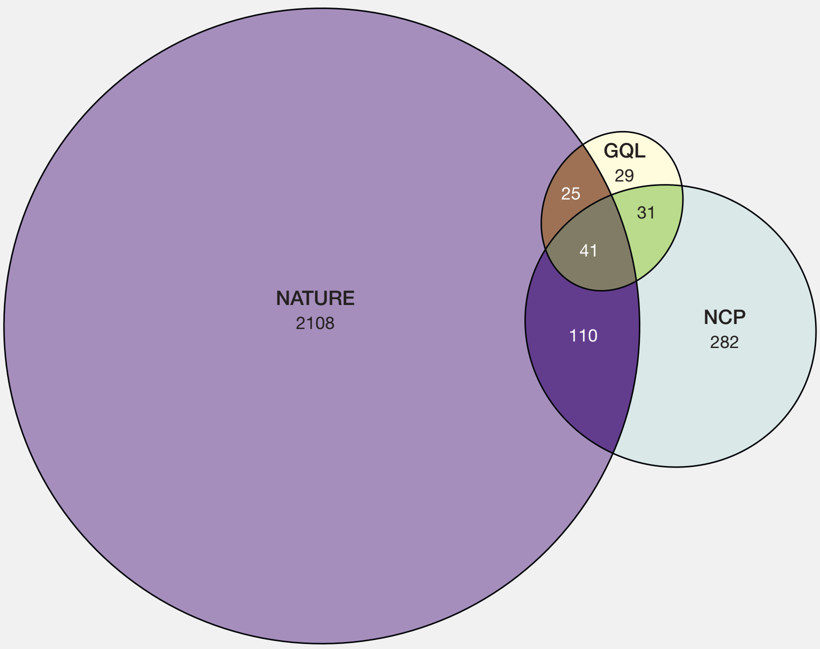


Figure 4 5 1 **Number of results in the systematic literature review (for details, see Appendix A4.1.1) which report projections of at least one indicator of nature, nature's contributions to people (NCP), or good quality of life (GQL).**

Overlaps of the circles indicate that a result contained trends for more than one group of indicators.

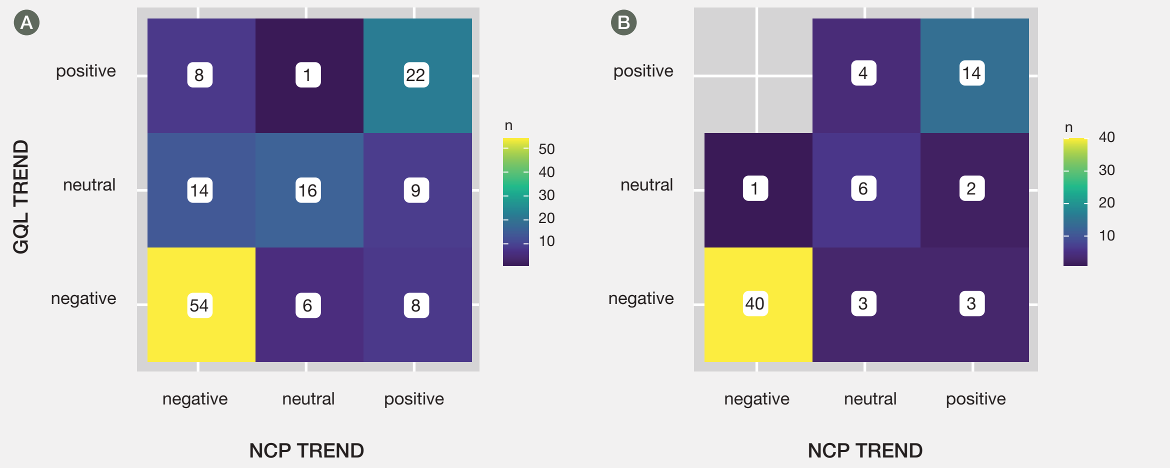


Figure 4 5 2 **Heatmap showing the relationship between negative, neutral and positive trends reported for indicators of nature and nature's contributions to people (NCP, left panel, A), and NCP and good quality of life (GQL, right panel, B) in output of the models and global scale scenarios from the systematic literature review (Appendix A.4.1). n: number of results reported (i.e. multiple results per paper possible).**

of correlation is neither quantified, nor linked to any potential feedback effects that can dampen or amplify the drivers impacts on nature, NCP and GQL (section 4.5.1). There are a few numbers of negative correlations between nature, NCP and GQL indicator trends, which, although found in a lower proportion, can represent difficult trade-offs between different policy targets, e.g. between conservation and food provisioning targets (section 4.5.2).

4.5.2 Feedbacks

Feedbacks are processes that either reinforce or degrade the resilience of a stable state (Briske *et al.*, 2006), with both damping (also known as negative or balancing) and amplifying (also known as positive or reinforcing) feedbacks acting together or separately in a complex system to hold it in a particular state. A compilation of studies illustrative for feedbacks can be found in the Appendix (Table A4.5.2).

Feedbacks are well documented in the climate system (Ciais *et al.*, 2013). For example, increases in atmospheric concentration of CO_2, warmer temperatures and/or altered precipitation impact uptake and release of CO_2 in vegetation and soils, which in turn amplifies or dampens the original forcing via feedbacks on atmospheric CO2. Along coastlines, global sea level rise, temperature extremes and storm surges are projected to damage marine vegetated habitats and decrease wetlands area (Crosby *et al.*, 2016; Hoegh-Guldberg *et al.*, 2018), with potential negative feedbacks on climate change as these areas play key role in carbon burial and sequestration (Duarte *et al.*, 2013; section 4.2.2.2.2). In terrestrial systems, shifts in vegetation cover associated with climate change and atmospheric CO_2 (such as changes in woody type and cover, reduction of permafrost and peatlands, or shifts in fire regimes) play additional important roles in these dynamics (see section 4.2.4.1; Achard *et al.*, 2014; Arneth *et al.*, 2010; Davidson *et al.*, 2012; Lenton *et al.*, 2008; Lenton & Williams, 2013; Pearson *et al.*, 2017; Stocker *et al.*, 2013). In addition, reduced evapotranspiration due to climate change (or deforestation) feeds back on surface humidity, formation of regional cloud or rainfall which could also enhance forest vulnerability to fire and drought (Avissar & Werth, 2005; Devaraju *et al.*, 2015; Lenton & Williams, 2013; Quesada *et al.*, 2017b; Ray *et al.*, 2006). However, there remain large uncertainties in the magnitude and direction of feedbacks (Arneth *et al.*, 2010; Friedlingstein *et al.*, 2014; Raes *et al.*, 2010; Roy *et al.*, 2011; Stocker *et al.*, 2013).

Feedbacks also exist in coupled socio-ecological systems (and hence between nature, NCP and GQL; Hersperger *et al.*, 2011; Hull *et al.*, 2015; Robinson *et al.*, 2017). For instance, infrastructure used for extraction and use of natural resources generates wealth, which amplifies technological development and further extraction of resources. As the demand of a natural resource intensifies, its economic value increases. To seek monetary profits, exploitation increases as well and as long as the demand is high, economic value and exploitation continue to increase (Cinner *et al.*, 2011; Leadley *et al.*, 2010, 2014; Walker *et al.*, 2009. A social driver like market demand increases the value of natural resources with increasing scarcity of the resource. This negative feedback starts to be accounted for in fishing scenarios, with for example, high short-term economic incentives to exceed sustainable exploitation targets of marine resources, potentially leading to increases in fishing capacity and rapid depletion of fish stocks (Merino *et al.*, 2012). This often happens with large predatory fishes that are of high monetary value (Tsikliras & Polymeros, 2014). Overfishing leads to their depletion, new global markets develop for alternative species in turn (Quaas *et al.*, 2016), often their own prey, which leads to further depletion of marine resources (Steneck *et al.*, 2011). In addition, economic market feedbacks in response to a conservation intervention can hinder conservation efforts (Lim *et al.*, 2017). In this case the price increase of e.g., timber following future logging bans or other protective measures such as protected areas might be counterbalanced by illegal trade and enhanced logging elsewhere ("leakage") and these unintended feedbacks on timber supply via market responses could be amplified even further if interventions shift the competitive ratio of efficient to non-efficient producers. Leakage effect from protected areas could also take place, when protected areas reduce threats within their boundaries by displacing a part of these threats into adjacent areas (Renwick *et al.*, 2015).

One of the key interactions between climate change and socio-economic changes is human population distribution and mobility. Climate change-induced migration, also referred to as "environmental migration" (Black *et al.*, 2011), can exert additional pressure on the environment in regions of migratory influx of people, which in turn exacerbates degradation of resources. Likely, migrants would choose urban or developed areas as their destinations (Tacoli, 2009). Enhanced pressure on resources around cities (see 4.3.3) following the influx of large number of people might lead to further environmental degradation, and pressure of people to move elsewhere. There are inherent difficulties in explicitly monitoring and predicting the effects of environmental migration caused by migration due to lack of comprehensive data (Kniveton *et al.*, 2008). However, evidence from the past (including non-environmental migration) can already illustrate the potential impacts (Reuveny, 2007).

Changes in value systems and lifestyle, sense of nature and loss of indigenous or local knowledge can be side effects of globalization and commercialization that ultimately impacts the GQL which in turn leads to more exploitation of natural resources (Hubacek *et al.*, 2009; Reyes-García *et al.*, 2013; Uniyal *et al.*, 2003; Van der Hoeven *et al.*, 2013). Robust identification and quantification of feedbacks is a challenge for future scenario projections, in part because of teleconnections and telecoupling that need to be considered (Liu *et al.*, 2013). Both are interactions over distances; teleconnections refer often to interactions in the natural environment such as through atmospheric transport or ocean currents, while telecoupling explicitly acknowledges that in today's world interactions occur in coupled human-environment systems (Liu *et al.*, 2013; Robinson *et al.*, 2017). Global scale scenarios and models that would allow to assess the complex interactions between nature, NCP and GQL, and to identify the role of amplifying or damping feedbacks not only locally but also between regions do not yet exist.

4.5.3 Trade-offs

The use of a given ecosystem service by human societies affects in most cases the availability of other ecosystem services. In many cases trade-offs arise, especially between material NCP vs. regulating NCP and biodiversity (see sections 4.3.2 and 4.3.3; Bennett *et al.*, 2009; Bonsch *et al.*, 2016; Carpenter *et al.*, 2017; Clark *et al.*, 2017; Di Minin *et al.*, 2017; Krause *et al.*, 2017; Lafortezza & Chen, 2016; Powell & Lenton, 2013; Seppelt *et al.*, 2013; Tscharntke *et al.*, 2012; Vogdrup-Schmidt *et al.*, 2017). Similar results have been found across all the IPBES regional assessments (IPBES, 2018b, 2018e, 2018c, 2018d) and UNEP's Global Environmental Outlooks (e.g., UNEP, 2012). In most future scenarios, the demand for material NCP increases because of population growth and consumption pattern changes (Popp *et al.*, 2017), which can be considered principal drivers for the declines in regulating NCP and biodiversity. In absence of targeted policy, future global demand for food, energy, climate and biodiversity may be very difficult to achieve simultaneously (e.g., Henry *et al.*, 2018; Obersteiner *et al.*, 2016; von Stechow *et al.*, 2016). Trade-offs (but also co-benefits) in ecosystem service supply can be considered important components of feedback loops (see 4.5.2), since in the long term a substantial decrease in regulating services will also negatively affect provision of material services that depend on the regulating ones (Cavender-Bares *et al.*, 2015). For instance, the destruction of pollinator habitat as part of agricultural expansion or intensification, can lead to declines in food production (IPBES 2016b), resulting in the need for further agricultural expansion (and associated further loss of pollinator habitat). The implications of future trade-offs will be influenced by regionally specific biophysical settings in combination with cultural preferences and thus should be considered in decision-making (Cavender-Bares *et al.*, 2015) (see chapter 6). However, since scenarios and models for many NCP are non-existent or incipient, many trade-offs and synergies remain unknown (Mach *et al.*, 2015). In particular cultural services are usually not considered in scenarios development or in models (see section 4.3), therefore future trade-offs with material and non-material aspects are poorly understood.

Food, bioenergy and water

Increasing consumption of food, and associated terrestrial and marine food production sectors, are seen as a main driver of biodiversity loss. Overexploitation of wild marine resources is expected to increase in the future under current management schemes (Costello *et al.*, 2016; see section 4.2.2.3.1) but could be alleviated by the growth of the aquaculture sector (Merino *et al.*, 2012; Quaas *et al.*, 2016). However, aquaculture development is challenged by a number of trade-offs related to fishmeal provisioning (Blanchard *et al.*, 2017) from wild marine resources (and potential further decline of marine populations, especially those serving as prey for already overexploited marine predators) or from cereal and soya production affecting land-based food production. Terrestrial ecosystems are impacted through cropland expansion as well as intensification on existing agricultural land and associated inputs of water and fertilizer (Foley *et al.*, 2011; Tilman *et al.*, 2011; Tilman & Clark, 2015). The pressure on agricultural systems will be increasing not only due to the continued population growth but also due to projected changes in dietary preferences towards meat-based protein intake in many countries. Under continuation of current trends, global food, water or timber demands are estimated to increase by 30% (timber), 65% (food and feed) and 75% (water) by 2050 (van Vuuren *et al.*, 2015).

Land-based climate change mitigation requires additional land area (e.g. for bioenergy or reforestation), which is projected to be lowest in sustainability scenarios that assume changes in consumption patterns (e.g., 250-530 Mha, SSP1/RCP2.6), and highest in scenarios that describe a world with large regional competition (e.g., 250-1500 Mha, SSP4/RCP2.6) (Popp *et al.*, 2017). In view of food and water demands of a growing human population, the question remains whether (and where) the required land area would be available for large bioenergy plantations or afforestation/reforestation efforts. Likewise, large direct or indirect side effects have been shown to arise for the global terrestrial ecosystem carbon balance, and hence climate regulation, other ecosystem functionality and biodiversity (Bird *et al.*, 2013; Jantz *et al.*, 2015; Krause *et al.*, 2017; Kraxner *et al.*, 2013; Melillo *et al.*, 2009; Plevin *et al.*, 2010; Santangeli *et al.*, 2016). It is well documented that the use of ecosystem services regionally will impact ecosystem functioning and services in other regions (Jantz *et al.*, 2015; Krause *et al.*, 2017; Seppelt *et al.*, 2013; and see section 4.3.3). For tradeable goods, and in absence of changing demand, land-use change in a given region (for instance, converting land to bioenergy rather than food production) will result in compensatory land-use changes elsewhere (for instance, conversion of natural habitat to food production) (Bird *et al.*, 2013; Krause *et al.*, 2017; Kraxner *et al.*, 2013; Melillo *et al.*, 2009; Plevin *et al.*, 2010).

Future land-use change scenarios with Integrated Assessment Models (Popp *et al.*, 2017) assume that land for bioenergy growth or afforestation and reforestation can be freed up through continued strong increases of crop yields (Bijl *et al.*, 2017; Bonsch *et al.*, 2016; Humpenoder *et al.*, 2015; see also **Table 4.1.6**, section 4.1), but the environmental and societal issues associated with the intensification of agricultural production are insufficiently considered in these scenarios. For an end-of-century 300 EJ bioenergy target to be produced from plants, Bonsch *et al.* (2016) found a doubling of global agricultural water withdrawal and a bioenergy production area of 490 Mha, or a land requirement of 690 Mha if no irrigation of bioenergy plants is considered. The latter increased to approximately 1000 Mha land for bioenergy if technology effects on increased yields would be only half of those in bioenergy than in food crops (Bonsch *et al.*, 2016). Krause *et al.* (2017) found both increases and decreases in different ecosystem functioning in response to scenarios under a RCP2.6 umbrella that included large-scale land-related climate change mitigation efforts, with large variability across regions and land-use scenarios. Large nitrogen losses were simulated in response to fertiliser needs to support yield increases, indicative of air and water pollution. Competition for land in climate change mitigation scenarios based heavily on bioenergy production has also been shown to increase food prices (Kreidenweis *et al.*, 2016). Detrimental societal impacts will arise if these price increases cannot be met by economic growth. It has now been consistently demonstrated that regional surface temperature can be strongly affected by land cover change, arising from altered energy and momentum transfer between ecosystems and atmosphere, with either an increase or decrease in temperature depending on the geographic context (Alkama & Cescatti, 2016; Li *et al.*, 2015; Perugini *et al.*, 2017; Quesada *et al.*, 2017a). Thus, changes in surface climate arising from large-scale land cover change in mitigation efforts can regionally amplify or reduce climate change. Large-scale land-based climate change mitigation efforts need to take account of unintended consequences on ecosystems that could undermine climate regulation or provisioning of a range of important ecosystem services.

An important element of the SSP1/RCP2.6 scenarios which limit global warming to about 2°C is that much of agriculture and bioenergy production relocates from high-income temperate regions to low-income tropical ones (van Vuuren *et al.*, 2011) where most of freshwater diversity is concentrated (Tisseuil *et al.*, 2013). Deforestation, extraction of high amounts of water withdrawal for irrigation, and use of pesticides and fertilizers to increase productivity in expanding bioenergy croplands are known to adversely affect natural aquatic systems and their biodiversity, notably fishes through local extinctions and alteration of their community structure (sections 4.2.3.2; 4.2.3.3). Inland fisheries are particularly important in tropical developing countries and currently provide the major dietary protein source for well over half a billion people (FAO, 2016; Lynch *et al.*, 2016). An increase in bioenergy production in these low-income food-deficit countries is thus expected to strongly impact fisheries and compromise further their food security.

4.5.4 Co-benefits

In order to sustain and enhance the future supply of NCP, in particular between regulating and non-material contributions (Ament *et al.*, 2017; Hanspach *et al.*, 2017; Potts *et al.*, 2016; Vogdrup-Schmidt *et al.*, 2017), changes in consumption patterns, globally, alongside changes in supply has emerged as crucial in scenarios of ecosystem change, NCP and GQL. In this context, reduction of food waste and shifts in diets are most illustrative.

Enhancing efficiencies in the food system, including the reduction of food losses and waste that occurs at several stages in the food production system, has large potential to enhance food security in a world where still every third person is malnourished, and 815 million people are hungry (FAO *et al.*, 2018). It may also free up land for other uses such as for biodiversity conservation, and entail additional co-benefits such as reduced greenhouse gas emissions from the land sector, and reduced irrigation water needs which will also release pressure on freshwater pollution and biodiversity (Alexander *et al.*, 2017b; Godfray *et al.*, 2010; Kummu *et al.*, 2012; Pfister *et al.*, 2011; Smith *et al.*, 2013). Nearly one-quarter of total freshwater used today in food crop production could be spared if wastes and losses in the food system were minimized (Kummu *et al.*, 2012). Nearly 10% of the agricultural land area could be spared globally through halving consumer waste arising from over-consumption in some sectors of society (Alexander *et al.*, 2017b). For the period 1961-2011, waste and losses in the food system were estimated to sum to approximately 68 $GtCO_2$ equivalents (Porter *et al.*, 2016).

A number of studies address the potential of reducing future expansion of croplands and/or reducing environmental impacts from agriculture and pastures (especially climate regulation related to reduced greenhouse gas emissions) through changes in diets. Studies that explore dietary scenarios of either reduced consumption of animal protein (combined with a globally more equitable distribution of animal protein) or no consumption of animal protein estimate that between about 10% and 30% of today's area under agriculture could be freed for other purposes (Alexander *et al.*, 2016; Bijl *et al.*, 2017; Ridoutt *et al.*, 2017 and references therein; Roos *et al.*, 2017; Tilman & Clark, 2014; Wirsenius *et al.*, 2010). A further positive side effect of these dietary shifts are health benefits in overweight population categories (Roos *et al.*, 2017; Tilman & Clark, 2014). The evidence base on impacts of diets on biodiversity, arising from reduced agricultural expansion is limited and context specific; however, a consumption-change scenario that included, among other changes in lifestyle, a shift towards a more vegetarian diet found positive effect on biodiversity of terrestrial mammals, in particular those with large ranges (Visconti *et al.*, 2015).

Additional cost-efficient measures to address environmental challenges have been demonstrated in studies that investigated optimizing crop distribution or the combination of several climate change mitigation options, while respecting food and fiber demand and conservation needs (Davis *et al.*, 2017; Griscom *et al.*, 2017). Through the globally optimal distribution of major crops, agricultural water use could be reduced by 12-14%, in a process-based crop-water-model combined with spatial information on yields, with large co-benefits for calorie and nutrient supply (Davis *et al.*, 2017). In particular, a move from some of the main cereal and sugar crops to e.g. roots, tubers and nuts underpinned these positive impacts. While cultural barriers, such as dietary preferences, will prevent to reach these potential gains of reduced water loss and enhanced food security, the analysis nonetheless puts forward a cost-efficient strategy towards sustainable intensification that could maintain small-holder farm systems and avoid large investments in technology-driven agriculture. From the perspective of contributing towards the achievement of the 2°C warming goal, economically-constrained greenhouse-gas reduction measures in the agriculture and livestock sector were estimated to contribute 1.5-4.3 Gt CO_2-eq. a^{-1} emission reductions (Bustamante *et al.*, 2014; Smith *et al.*, 2013; Tubiello *et al.*, 2015), which can be substantially enhanced further if consumer demand measures were also included. Recently, a combination of 20 different management measures in forests, agricultural land and wetlands achieved a maximum reduction of ca. 11 Pg C_{eq} a^{-1} when constrained by food security, conservation considerations and cost-efficiency (Griscom *et al.*, 2017). In addition, the future of land use and its impacts on biodiversity and ecosystem services depends on opportunities for building climate-resilience across sectors, including fisheries and aquaculture production systems (Blanchard *et al.*, 2017). As fish production has been the fastest growing food industry for the last 40 years, outpacing growth in all other livestock sectors (Béné *et al.* 2015), adaptive sustainable fisheries management (Costello *et al.*, 2016; Gaines *et al.*, 2018) combined with the development of sustainable low input and low impact aquaculture could generate co-benefits for food security, conservation of biodiversity, and climate regulation.

4.5.5 Regime Shifts, Tipping Points and Planetary Boundaries

There is a growing body of evidence that socio-ecological systems can be pushed past certain limits, beyond which they are profoundly altered in their structure and functioning. These are variously referred to as “regimes shifts”, “tipping points” and “moving beyond planetary boundaries” and can be caused by a number of mechanisms (see Table A4.5.3 in Appendix 4.5). In some cases, these shifts occur rapidly and are difficult to reverse (Hughes *et al.*, 2013). The term “regime shifts” encompasses most of the concepts found in the definitions of tipping points and planetary boundaries, and so it will be used throughout this section except in cases where the distinction between concepts is important (Hughes *et al.*, 2013; Leadley *et al.*, 2014).

In some cases, regime shifts arise from relatively well understood physical and biological processes or feedbacks (Table A4.5.2) and have been included in models. In many cases, however, regime shifts arise from the complex interplay and feedbacks between people and nature (Table A4.5.3), and in general have not been well accounted for in scenarios and models. In addition to the underlying mechanisms, the spatial and temporal scales of regime shifts are extremely important when assessing the importance of their impacts and the evidence base for their past, current and possible future occurrence (Hughes *et al.*, 2013; IPCC, 2018; Steffen *et al.*, 2018).

Regime shifts that occur over the span of several years to several decades are well documented at local to small regional scales and occur frequently in response to increasing human pressure. In some cases, these can be reasonably well foreseen with scenarios and models. These regime shifts have large impacts on nature, nature’s contributions to people and good quality of life at local scales, but may also have important impacts at much larger scales when they occur in many places at the same time (Leadley *et al.*, 2014). The collapse of local and regional fisheries is a salient example in marine ecosystems. The accumulation of these collapses at local to regional scales has reached a point where a substantial fraction of the world’s fisheries is either collapsed or near the limits at which they could collapse (section 4.2.2.3.1). Land degradation is a good example in terrestrial socio-ecological systems. Land degradation is often the result of complex human-nature interactions and therefore the causes of land degradation are not the same everywhere in the world (Table A4.5.3). Land degradation is, however, sufficiently widespread that it is “negatively impacting the well-being of at least 3.2 billion people” (IPBES, 2018a). The increasing widespread phenomena of eutrophication of ponds and lakes by excess nutrient input is an excellent example in freshwater ecosystems (section 4.2.3.3). The common characteristics of these examples are that i) there is a rapidly increasing number of areas affected by these regime shifts, to the point that they now have global scale implications for nature and people, ii) scenarios and models of business-as-usual trajectories indicate that the pressures driving these regime shifts will increase over the coming decades in many regions and iii) scenarios and models suggest there are plausible alternative pathways that avoid aggravation of these regime shifts and, in many cases, lead to partial restoration of these systems (e.g., land restauration scenarios in IPBES, 2018f; Leadley *et al.*, 2010).

There are several regime shifts at large regional scales underway that have been initiated by human disturbance and are projected to have direct impacts on biomes over the next several decades (Leadley *et al.*, 2010; Steffen *et al.*, 2018). There is strong evidence that large-scale regime shifts have begun for tropical coral reefs (section 4.2.2.2.2, **Box 4.2.3**), large-scale changes in marine communities and ecosystem function due to the loss of summer sea ice in the Arctic Ocean (sections 4.2.2.2.1 and 4.2.2.2.4); and degradation of permafrost and increasing woody vegetation in arctic tundra systems (Settele *et al.*, 2014; section 4.2.4.1.1). Models foresee rapid aggravation of these regime shifts over the coming century (IPCC, 2018; Leadley *et al.*, 2010; sections cited above). Further rapid, global-scale degradation of tropical coral reefs — which are driven by the combined impacts of climate change, ocean acidification, sea level rise, pollution and overexploitation — is of particular and immediate concern because of the severe impacts on biodiversity and because large human populations depend on coral reef ecosystems for food, income and shoreline protection (IPCC, 2018; see **Box 4.2.3** and section 4.3.2.1). Several other postulated regime shifts at large regional scales are more uncertain. For example, the large-scale collapse of the Amazonian rainforest has been postulated due to the combined effects of deforestation and climate change and regional scale feedbacks, but observational and experimental evidence, as well as modeling studies are equivocal about the likelihood of a large-scale regime shift (Settele *et al.*, 2014; section 4.2.4). There are also early signals of tree dieback in boreal forests due to climate change, and some models project large-scale boreal forest degradation over the coming century, but the spatial scale and magnitude of this regime shift remains speculative (Settele *et al.*, 2014). A key feature of these regime shifts is that they are driven in large part by climate change and/or rising atmospheric CO_2 concentrations and therefore require strong international actions to reduce greenhouse gas emissions (IPCC, 2018). However, adaptation to and attenuation of climate change impacts also require additional local and national scale efforts to reduce other pressures under biophysical and economic limits (e.g., Smith *et al.*, 2016).

The likelihood of the occurrence of regime shifts, tipping points, or boundaries being exceeded for biodiversity and ecosystem services at global scales are speculative. The planetary boundaries literature posits that there are a few indicators that can be used to identify boundaries beyond which the planet will leave the relatively stable "safe operating space" that it has operated in over the last 10 millennia (Hughes *et al.*, 2013). There is growing evidence that some indicators, especially for climate change, are useful for identifying potential global scale regime shifts (Steffen *et al.*, 2018), but there is little evidence yet for a global scale indicator for biodiversity loss or degradation of ecosystem integrity (Mace *et al.*, 2014). It has also been postulated that the Earth is approaching a global scale regime shift that would lead to a massive loss of biodiversity and incalculable impacts on people (Barnosky *et al.*, 2012; Brook *et al.*, 2013; Steffen *et al.*, 2018). The mechanisms for these Earth scale tipping points are not well defined and not included in any models (Hughes *et al.*, 2013), but the combined effects of several large-scale regime shifts including the irreversible melting of the Greenland ice sheet, the loss of the West Antarctic ice sheet and several other regime shifts could plausibly combine to create a shift to a very hot global climate regime once moderate levels of global warming have been exceeded (Steffen *et al.*, 2018). There are also plausible mechanisms leading to telecoupling between regions such as atmospheric transport, movements of organisms, or human migrations that can greatly increase the spatial extent or impact of regime shifts (Leadley *et al.*, 2014). While these global scale regime shifts and planetary boundaries are speculative, the potential magnitude and scale of the impacts are so large that further work to understand and model the underlying mechanisms is essential.

4.6 LINKS TO SUSTAINABLE DEVELOPMENT GOALS, AICHI BIODIVERSITY TARGETS AND OTHER INTERNATIONAL OBJECTIVES FOR NATURE AND NATURE'S CONTRIBUTIONS TO PEOPLE

4.6.1 How good will we be at reaching international biodiversity and sustainability targets beyond 2020?

Scope: How are scenarios and models addressing international biodiversity targets and sustainability goals and what insights do they provide? This section builds on Chapter 3 (Progress towards Aichi Biodiversity Targets) by looking at projections beyond 2020.

The Aichi Biodiversity Targets agreed to in the Strategic Plan for Biodiversity 2011–2020, targets in other multilateral environmental agreements, and the Sustainable Development Goals (SDGs) have been adopted to motivate actions to sustain nature and its contributions to the promotion of human well-being and sustainable development (Chapter 3). Although many of the SDGs do not explicitly focus on nature, with the notable exception of goals related to life below water and life on land (SDGs 14 and 15), the supply of multiple ecosystem services is critical to achieving many SDGs. And despite the fact that relatively few SDG targets (as currently expressed) map directly onto nature or its contribution to people, most Aichi Biodiversity Targets are clearly related to SDGs.

Analysis of the data sourced from the systematic literature review (Appendix A4.1.1) shows that despite the importance of SDGs and Aichi Biodiversity Targets for sustainability and human well-being, few scenario analyses have a specific focus on achieving them, at least at global scale. Scenarios of biodiversity and ecosystem services can contribute significantly to policy support in all the major phases of a policy cycle, including agenda setting and policy design (Ferrier *et al., 2016; IPBES, 2016b, figure SPM3)*. Several scenario and modeling analyses provide useful indications related to policy targets, albeit indirectly **(Figure 4.6.1)**, but the vast majority of these relate to species declines and extinctions, therefore informing only on Aichi Target 12 (conservation of threatened species) and

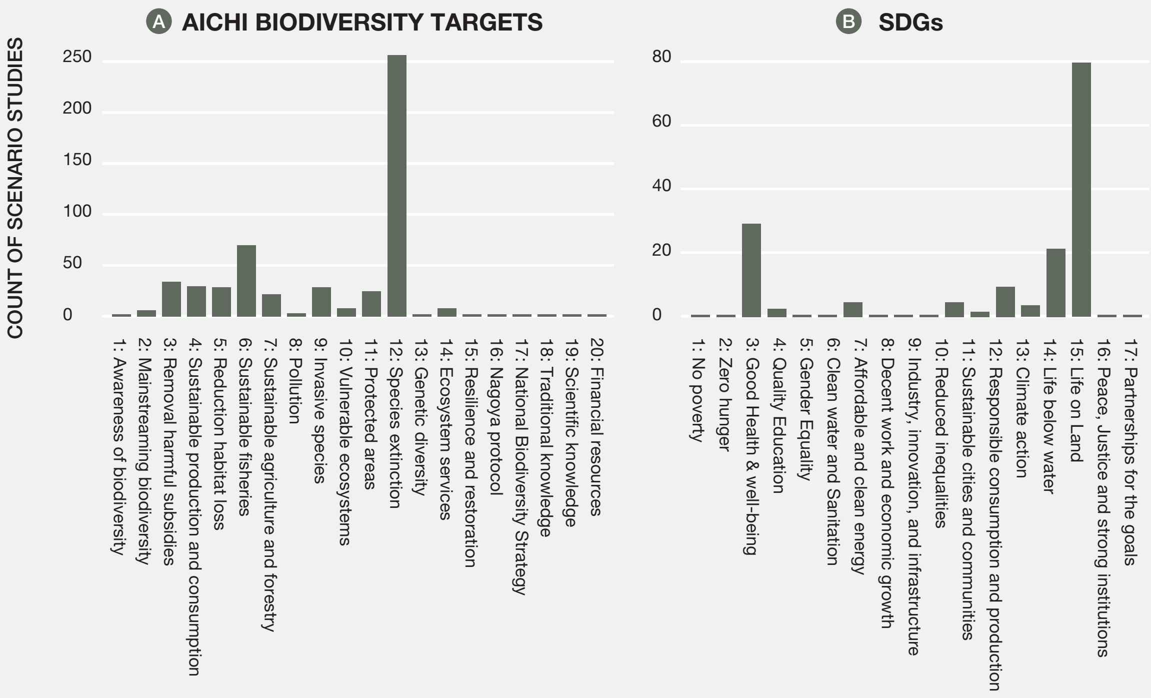


Figure 4 6 1 **Number of scenario studies addressing Aichi Biodiversity Targets A and SDG thematic policy areas B based on the systematic literature review carried out for this chapter (Appendix A4.1.1).**

a small subset of targets related to SDG 15 (life on land). The reason for this imbalance probably lies in the different level of development of methods in the research community. Models for projecting species distributions under climate scenarios (which relate to Target 12 and SDG 15) are well established and widely used in the literature, while the exploration of other targets and goals is hampered by the scarcity of appropriate models at global scale. Global scale scenarios specifically addressing Aichi Biodiversity Targets are scant **(Figure 4.6.1A)**, and most of them relate to Target 12 (conservation of threatened species) and 6 (sustainable fisheries). Scenarios addressing SDGs focus mostly on SDG 15 (life on land), 2 (zero hunger) and 14 (life below water), but this also reflects the fact that the focus of the systematic literature review for this chapter was restricted to biodiversity and ecosystem services, rather than encompassing other societal goals. Therefore, the SDGs other than 14 and 15 represented in **Figure 4.6.1B** were addressed in conjunction with SDG 14, 15 or both.

For Sustainable Development Goals, scenario analyses are usually sector-specific (Obersteiner *et al., 2016)*, and a review of 22 modelling case studies has shown that it would be unlikely that any scenario modelling exercise could cover all (Allen *et al., 2017)*. Most studies focus on environment-economy interactions, such as greenhouse gases (GHG) reduction and impacts of this on growth and employment, and consideration of broader social issues is limited (Allen *et al., 2017)*. Various models have been used to assess SDGs including top-down system dynamics, macro-economic and hybrid models as well as bottom-up sectoral models across multiple sectors such as energy, agriculture, transport, land use, etc. (Allen *et al.,* 2016, 2017).

Biodiversity targets have been missed in the past for 2010 (Butchart *et al.*, 2010), and the mid-term progress towards Aichi Biodiversity Targets for 2020 was insufficient (Tittensor *et al.*, 2014). The world is still far or very far from achieving most of the Aichi Biodiversity Targets by 2020 (Chapter 3). Evidence from the limited number of scenario analyses from the systematic literature review (Appendix A4.1.1) shows that these targets are unlikely to be achieved even at some point in the future in most scenarios (2050 and beyond). However, for most targets, delayed achievement in the future is possible under some scenarios **(Figure 4.6.2)**. Recent scenario research has explored the likelihood that global biodiversity targets can be achieved by steering from business-as-usual to more sustainable socio-economic development trajectories. For example, Visconti *et al.* (2016) have projected policy-relevant indicators (Living Planet Index, LPI, and indicator of species abundance, and Red List Index, RLI, an indicator of extinction risk) for large mammals to 2050, comparing a reference scenario to sustainability scenarios (van Vuuren *et al.*, 2015).

Figure 4 6 2 **Achievement of Aichi Biodiversity Targets in the future (2050 or beyond) across different global scale scenarios, based on our systematic literature review (Appendix A4.1.1).**

N: number of indicators, with number of studies in parenthesis, each study usually projecting several different indicators. Many scenarios dealing with Aichi Biodiversity Targets did not report results in a way that could be interpreted as level of target achievement, therefore the numbers here are smaller than in **Figure 4.6.1**.

They showed that after a mid-term increase until 2030, biodiversity indicators would decline again afterwards as the projected effects of climate change outpace mitigation actions. This analysis showcases how scenario modelling links long-term results to short- and medium-term action. It has been proposed that for achieving future targets, bold goals like the CBD 2050 Vision be adopted, and that integrative policies for sustainable production and consumption (e.g., a shift towards a more balanced diet, Chapter 5) be adopted (Mace *et al.*, 2018).

The global results on achievement of biodiversity targets do not scale down to the IPBES regions where the same topic has been addressed. The IPBES regional assessment for Africa (IPBES, 2018g) found low likelihood to ever achieve most Aichi Biodiversity Targets, except Target 1 (awareness of biodiversity) and 14 (ecosystem services), for which the regional trend is positive. Under the "fortress world" archetype scenario (similar in characteristics to the "regional competition" archetype defined in this chapter, section 4.1), the trend in Africa is negative for all Targets. For Europe and Central Asia, sustainability scenarios are expected to achieve most Aichi Biodiversity Targets, but still fail a few (in particular Targets 1, awareness of biodiversity, and 17, national biodiversity strategies) (IPBES, 2018i). The information is not available for other IPBES regions.

If the global socio-economic development continues according to a business-as-usual scenario, it is likely that we will fail to achieve several biodiversity-related SDGs (SDG 14, Life below water, and 15, Life on land). Three-quarters of the scenario and models that address SDG 15 project that we will be far or very far from achieving it. A similar outcome is projected for SDG 14 **(Figure 4.6.3)**. In Europe and Central Asia scenarios of sustainable production and consumption are expected to achieve most SDGs (IPBES, 2018i). In this region, the economic optimism archetype scenarios are expected to achieve most SDGs, but notably fail SDG 14 and 15. A recent study stressed that under the current trajectory of socio-economic development, progress in SDGs related to poverty and social inclusion happens at the expense of the environment, and this will lead to missing environmental SDGs in most of the world countries (**Figure 4.6.4**; Spaiser *et al.*, 2017). This is attributed to the

Figure 4 6 3 **Achievement of SDGs across different global scale scenarios, based on our systematic literature review (Appendix A4.1.1).**

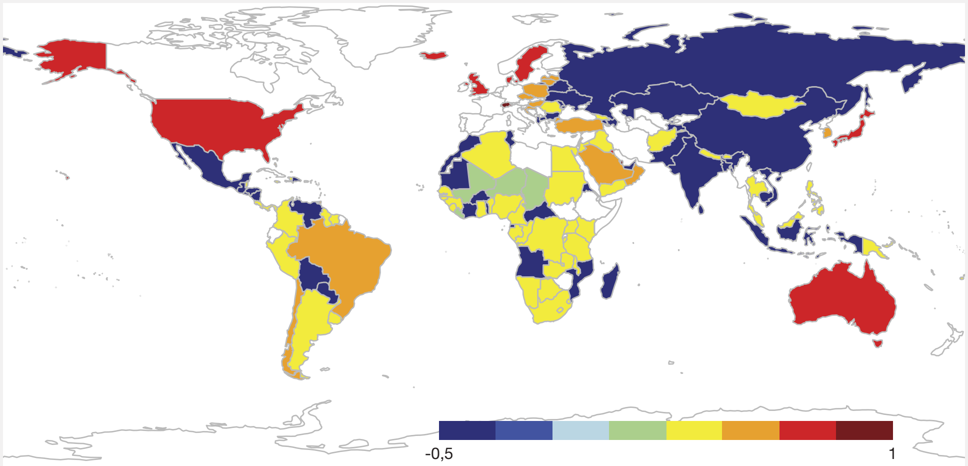
N: number of indicators, with number of studies in parenthesis, each study usually projecting several different scenarios. Many scenarios dealing with SDGs did not report results in a way that could be interpreted as level of target achievement, therefore the numbers here are smaller than in **Figure 4.6.1**. The systematic literature review focused on Nature and NCP, therefore SDGs other than 14 and 15 were captured only if they were assessed in conjunction with them.

focus on economic growth and consumption as means for development.

Several emerging issues have been identified as influential to the achievement of the SDGs. These include new scientific knowledge, new technological development, new scales or accelerated rates of impact, a heightened level of awareness and new ways to respond to a known issue (UN, 2016). Despite the uncertainty associated with these emerging issues, various aspects have been identified as necessary to achieve the SDGs. First, measuring progress at all scales, and integrating global targets with local policies is fundamental towards achieving the SDGs (Biermann *et al., 2017)*. Goal 17 on revitalizing the "global partnership", for example, will require increased funding and clear leadership (Biermann *et al., 2017)*. Increased funding is also one of the fundamental needs to achieve the SDGs in some regions within the African Continent (Kedir, 2017). Controlling consumption and demand remains an important issue. A recent work combing literature review and a comparison exercise of integrated energy-economy-climate models, AMPERE, found out that in order to achieve a 2ºC scenario, lowering the global growth of energy demand is key according to energy-economy-climate models (von Stechow *et al., 2016)*. Several local scenario studies provide useful insights towards achieving SDGs. In South Asia, industrial transformation, sustainable agriculture and innovations have been identified as key aspects to achieve SDGs (Kumar *et al., 2016)*. Participatory scenarios to achieve visions coherent to SDGs and to adequately adapt to future climate change impacts have also been applied with local communities in Indonesia (Butler *et al., 2015)*.

Scenarios have proven useful to identify and analyze synergies and trade-offs among biodiversity targets and SDGs. Glover and Hernández (2016) applied foresight techniques with experts in international development studies and found out that SDGs are not necessarily harmonious and mutually reinforcing but that trade-offs exist. According to this study, without strategic planning, advances towards one SDG might lead to negative consequences to others. Sustainable Consumption and Production policies (SDG 12), assessed through the GLOBIOM model, shows the need of inclusive policies among global development and

A **SDG INDEX 1**



B **SDG INDEX 2**

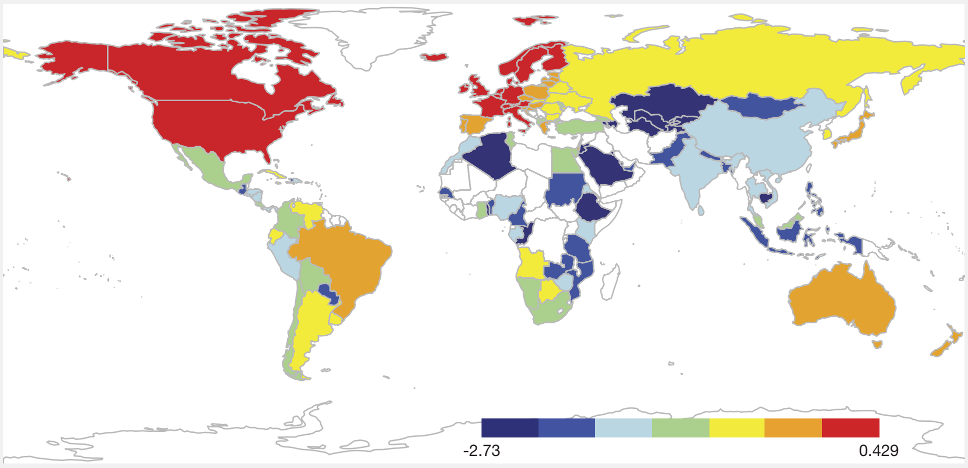


Figure 4 6 4 **World maps with countries being coloured based on an SDG index scores for 2011.**

The SDG index is based on the rate of change in three variables (child mortality, education, and CO_2 emissions) representing the three SDG pillars (ending poverty, social inclusion and environment). White colour indicates that an index could not be calculated, due to missing data in one or several of the predictors in the modelling approach used by Spaiser *et al.* (2017). The modelling approach used country and year specific data and combined confirmatory and exploratory factor analysis with dynamic systems modelling. Panel A reveals which factors are associated with development and negative values indicate a reduction of child mortality and an increase in education, as well as increased CO_2 emissions. Countries such as Russia, China and India present negative values of this indicator, showing that they perform well at reducing poverty and increasing socio-economic inclusion, but with associated environmental trade-offs in terms of CO_2 emissions. Developed countries like Australia, USA and UK, which have high levels of socio-economic development, show little room for improvement of their SDG index. Other countries like Brazil, Thailand and South Africa seem to present slower socio-economic development trends. Panel B uses a similar modelling approach but combined with a Bayesian model. The SDG index shows similar results for rich countries. However, contrarily to results of panel B, in panel A Russia presents a slow socio-economic development and several African countries such as Angola and Kenya make some progress in terms of socio-economic development. The trade-off between environment and the other two SDG pillars means that based on this analysis, under the current socio-economic model not all SDGs can be achieved together.

conservation agendas to minimize trade-offs and foster synergies (Obersteiner *et al.*, 2016). In another recent study using the IMAGE integrated assessment model, van Vuuren *et al.* (2015) have shown that achieving 2050 goals for both biodiversity and hunger would require a substantial increase in agricultural productivity per hectare, to accommodate a 50-70% increase in demand for food while halting the conversion of natural habitats. Another study found that implementing ambitious protected area expansion plans, under business-as-usual socio-economic trends, may result in a shortfall in productive land, as well as displacement of agricultural areas with consequential socio-economic

Table 4 6 1 **Synergies and trade-offs between different sustainability objectives.**

Colours indicate synergies (green) and trade-offs (red) in various intensities. Source: van Vuuren *et al.* (2015).

	Eradicate hunger	Halting biodiversity loss	Access to energy	Reduce air pollution	Mitigate climate change	Access to clean water	Balance nitrogen cycle
Eradicate hunger					More emissions from increased production (fertiliser. land expansion tractors) (*)	Increased water use for agriculture (*)	More emissions from increased production (fertiliser, manure (*)
Halting biodiversity loss	Less land for food production (*) Preservation or ecosystem services helps safeguard long-term food supply			Intact ecosystems contribute to better air quality	Fewer CO_2 emissions from land conversion and agriculture, new CO_2 sinks (*)	More gradual and uniform water flow, cleaner water Increased water use by permanent vegetation	More contribution of ecosystems in balancing nitrogen cycle
Access to energy	Increases income opportunities due to reduced time for fuel collection, better health	Less disturbance of local biodiversity for food collection		Less indoor and urban air pollution (*)	New emissions from modern energy offset by reduced traditional energy emissions (*)	Water requirement for power generation (small) (*)	
Reduce air pollution	Less negative impact of air pollution on crop yields	Less air pollutions impacts on biodiversity (*)	Higher energy prices		Depends on which air pollutants are reduced (*)	Less water pollution	Helps to reduce nitrogen deposition (*)
Mitigate climate change	Reduces negative impacts on yields (but also positive impacts) (*) Bio-energy competes for land with food production	Reduces negative impacts of climate change (*) Additional land for bio-energy (*)	Higher energy prices (*)	Less emissions of air pollutants due to lower fossil fuel use (*)		Negative impacts on precipitation patterns and evapotranspi-ration reduced (*)	Some positive impact N_2O emission reduction (*)
Access to clean water	Improved water for cooking Competition between agriculture and domestic purpose						
Balance nitrogen cycle	Reduction of fertiliser use (but also prevents toxic fertiliser levels)	Reduces pollution		Reduces air pollution	Some reduction of N_2O emissions		

Note: *denotes that the linkages is addressed quantitatively by the modelling framework.

impacts (Visconti *et al.*, 2015). Eradicating extreme poverty however, does not necessarily mean jeopardizing climate targets, even in the absence of specific climate policies and technological innovations (Hubacek *et al.*, 2017). Di Marco *et al.* (2016) explored the interactions between Aichi Biodiversity Targets 5 (reducing the loss of natural habitat), 11 (expanding the global coverage of protected areas) and 12 (conserving threatened species). They showed that the expansion of the global protected areas to 17% of land area resulted in different priorities of sites depending on whether the goal was to reduce habitat loss or conserve species. In addition, expanding protected area coverage to 17% to conserve threatened species would result in safeguarding 30% more carbon stock than targeting areas under high deforestation rates. The reason is that areas under rapid deforestation are not necessarily those with the highest capacity to stock carbon. While the figures relate to the Aichi Biodiversity Targets for 2020, the same trade-offs are likely to apply to post-2020 biodiversity targets. **Table 4.6.1** highlights some of the most significant synergies and trade-offs between different objectives associated with the Sustainable Development Goals.

Further modelling on policy targets that explicitly embodies nature into scenarios is of outmost importance. Scenarios developed for global environmental assessments have explored impacts of direct and indirect drivers on nature but have not embedded nature in the scenario itself. The effects of alternative pathways of socioeconomic development on nature have thus been assessed as one-way outcomes, ignoring the possible feedbacks of nature on the system (Rosa *et al.*, 2017). Existing scenarios ignore policy objectives related to nature protection. As targets for human development become increasingly connected with targets for nature, such as in the SDGs, the next generation of scenarios should explore alternative pathways to reach these intertwined targets and address feedbacks between nature, nature's contributions to people, and human well-being. Several desirable properties of this new generation of scenarios have been identified, including the use of participatory approaches, the integration of stakeholders from multiple sectors (for example, fisheries, agriculture, forestry) (Rosa *et al.*, 2017), and addressing decision makers from the local to the global scale (Biermann *et al.*, 2017).

4.6.2 How can the evidence from scenarios contribute to the development of future biodiversity targets and the 2050 vision?

Scope: How can scenarios and models help to reformulate the new set of targets? To address this issue, this section uses the Aichi Biodiversity Targets for 2020 as templates for setting the next generation of targets. Only a subset of the targets is discussed, with the purpose to demonstrate the type of considerations that should underpin the new targets. Existing scenarios and models for biodiversity and ecosystem services are used to explore: i) how targets can be formulated in ways that can more easily be understood and evaluated by both policymakers and practitioners; ii) which kinds of indicators, that come from observations and scenarios, can be used to evaluate progress towards the objectives of this target; and iii) what scenarios and models tell us about ambitious vs. aspirational targets, i.e. whether they can be achieved under plausible conditions represented by a variety of exploratory scenarios of societal and economic development.

4.6.2.1 Habitat loss and degradation (Target 5)

"By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced."

Analyses based on satellite remote sensing identified over the period 2000-2012 a net global loss of ca. 1.5 million km^2 of forest (Hansen *et al.*, 2013), including substantial loss of structurally intact pan-tropical forests (Tyukavina *et al.*, 2016). At current trends, even the target specified in the New York Declaration of Forests (to halve the rate of natural forest loss by 2020) is highly unlikely to be achieved (Zarin *et al.*, 2016). Under most future scenarios, the future net loss of natural habitats is partly counterbalanced by secondary regrowth. This is true for both forest and non-forest natural habitats (Hurtt *et al.*, 2011). Secondary habitat types typically host a fraction of the biodiversity present in primary habitats of the same type (Alkemade *et al.*, 2009; Newbold *et al.*, 2013), and this fraction depends on the integrity and age of the secondary vegetation. Therefore, numeric targets for the rate of loss of natural habitat are insufficient to capture the complex dynamics of habitat change, and the proportion of biodiversity that they retain compared to pristine habitats should also be considered.

From a scenario and modelling perspective, assessing the current and future state of forest globally is challenging for a number of reasons: 1) very different classifications as to what is a forest and which forest is considered intact, which one degraded (Alexander *et al.*, 2017c; Thompson *et al.*, 2013); 2) Most land-use change scenarios do not yet tend to consider environmental policies such as the Aichi Biodiversity Targets, the SDGs or REDD+ (Alexander *et al.*, 2017c; Eitelberg *et al.*, 2016, 2015; Popp *et al.*, 2017); 3) Integrated Assessment models that are often used to produce scenarios typically do not have the forest sector explicitly included at their core (Schmitz *et al.*, 2014); 4) Models that seek to assess future ecosystems from state of, e.g., carbon cycle and climate regulation perspective do not yet account well for forest (or other habitat) management (Arneth *et al.*, 2017).

In principle, activities to achieve Target 5 could have large co-benefits with achieving Targets 11 and 17, if protected area expansion could be dedicated to cover habitats of both high species density (in particular threatened or rare species) and regions of high carbon density (Di Marco *et al.*, 2016). Under otherwise unchanged conditions, scenarios in which multiple demands for land resources are aimed to be met resulted in intensification of croplands (adding to the "land sharing/land sparing" debate) and enhanced areas with tree cover (Eitelberg *et al.*, 2016). However, accounting for demand for protected area had no effect on reducing the projected loss of grassland, compared to business-as-usual (Eitelberg *et al.*, 2016). Maximizing forest habitat conservation as well as forest species conservation was estimated to be possible in 73% of the area identified to be also most appropriate for expanding the current protected area to meet Target 11 (Di Marco *et al.*, 2016).

Recent and projected trends in population growth and lifestyle (e.g., dietary changes), jointly with enhanced requirements for bioenergy crops are expected to maintain large pressures on further cropland expansion (Alexander *et al.*, 2017a; Eitelberg *et al.*, 2015). Agriculture is one of the largest drivers of biodiversity loss, and a large source of greenhouse gases and pollutants (McLaughlin & Kinzelbach, 2015; Newbold *et al.*, 2015). Therefore, achieving conservation goals alongside meeting demand for food and fibre, water, bioenergy and climate mitigation will require a dedicated effort that considers both changes in supply and demand, as well as equitable trade (Alexander *et al.*, 2017a; McLaughlin & Kinzelbach, 2015).

4.6.2.2 Sustainable fisheries (Target 6)

"By 2020, all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches [...]."

Whilst the objectives of Target 6 are relatively clear, some terms remain imprecise. The primary facets of the Target which remain loosely defined are the concepts of 'safe ecological limits' and 'no significant adverse impacts' (also the issue of 'vulnerable' ecosystems; see Target 10). 'Safe ecological limits' as a term lacks indication of whether these limits are structural (e.g. maintenance of facets such as ecosystem trophic structure or species composition) or functional (e.g. continued provision of goods and services). Without clarification, it is then difficult to know what aspects of ecosystems should be maintained, nor the level of degradation that is to be tolerated. Furthermore, the margins of safety are not clearly specified –how are these limits to be measured, quantified, and monitored? How close to the 'safe ecological limit' is acceptable? Finally, the term "safe limits" has been used with many contexts including the planetary boundary framework (Steffen *et al.*, 2015) and, therefore, might benefit from clarification. It is important not to confound 'safe ecological limits' and 'safe limits for humanity' since these refer to very different reference baselines, as well as very contrasted spatial and temporal scales.

Regarding 'no significant adverse impacts', the lack of specificity here is to do with the meaning of the word 'significant' (note that Target 5 also includes this terminology). Scientifically, 'significant' generally has a statistical meaning, indicating evidence at some level of likelihood that an effect is not attributable to chance. It seems unlikely that this is the intended meaning here, but significant can be so broadly interpreted as to make consistency of application across national and regional scales extremely challenging.

Quantification of progress towards this target through appropriate indicators has shown that at least some indicators exist for monitoring resource state (e.g., the proportion of fish stocks within safe biological limits), the pressures on it (e.g., global effort in bottom trawling), and fisheries responses to pressures on fish stocks (e.g. Marine Stewardship Council certified fisheries). However, indicators of whole ecosystem (as opposed to stock) status and recovery plans remain limited or absent, and the scope and alignment of existing indicators varies. Recent focus has been put on ecosystem-based indicators for assessing the state of exploited species and the ecosystems they are embedded in (Coll *et al.*, 2016; Shin *et al.*, 2012), some of which have been retained in the list of IPBES "Highlighted indicators" but still lack global scale coverage for nations to be able to report routinely (proportion of predators, mean fish size).

Projecting plausible futures for marine and aquatic biological resources is aided by the fact that there has been a long history of model development for these systems, with a particular profusion of models emerging over the past decade or so (Fulton, 2010). Models range from single species stock assessment models to whole ecosystem approaches, and in some cases such models incorporate large parts of the socio-economic and management components as well as the biological ones (Nielsen *et al.*, 2018). The heterogeneity of models is also beginning to be addressed by applying standardised ensemble modelling approaches across specified scenarios (Tittensor *et al.*, 2018b), akin to model intercomparison studies in the climate and earth science communities. Perhaps more challenging is the specification of socio-economic storylines that can then be translated into projections that can be used to force ecosystem models. While storylines have recently been in development at both regional (CERES, 2016) and global (Maury *et al.*, 2017) scales, specifying how the developments in economics, management, and governance that are outlined in scenarios can then be used to force models, especially spatially explicit models, is difficult. Furthermore, management and stewardship of marine resources remain varied among nations in terms of capacity, approach, and effectiveness (Bundy *et al.*, 2017). Management regimes can also change radically and rapidly in response to changes in national policy environments (e.g., the enactment and amendments of the U. S. Magnuson-Stevens Fishery Conservation and Management Act), and resource management plays an integral role in terms of the status of both target species and ecosystems (FAO, 2016), and furthermore adaptation to a changing climate. Nonetheless, the continued development of scenarios, together with the broad and growing range of marine ecosystem models at multiple scales, suggests that Target 6 can be usefully and increasingly informed by their application.

Broadly speaking, the development of future policy targets needs to further incorporate the role of climate change on the sustainability and use of aquatic resources. Furthermore, objectives may need to be reframed or at least clarified in order to address the challenges of measuring ‘significant adverse impacts’ and ‘safe ecological limits’ whilst still allowing for national level variation in how objectives are attained and recognizing differences in capacity for stewardship of aquatic resources. When specifying targets, it also needs to be made clear whether the goal is maintaining ecosystem structure, the provision of goods and services (including contributions to food security), or both. Currently, there is also potential overlap between Targets 6 and 7, in that Target 6 includes the management and harvest of fish and invertebrate stocks and aquatic plants, which will be increasingly linked to the development of aquaculture in the future that is addressed in Target 7 (section 4.2.2.3.1). Given the continued growth in the importance of aquaculture, its impacts on broader ecosystem health, including indirect effects such as fishing wild stocks to provide fishmeal for aquaculture (not explicitly mentioned in Target 7, but implicitly included in Target 6) needs to be further integrated into future targets. Similarly, at present there is overlap with Target 10, since anthropogenic impacts on coral reefs (and other vulnerable aquatic ecosystems) include those integrated into Target 6.

4.6.2.3 Sustainable agriculture (Target 7)

“By 2020, areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.”

The scientific community has been engaged in a controversial debate about whether biodiversity conservation can better be achieved by improving habitat availability and quality on farmland (i.e. through wildlife-friendly farming – “land sharing”), or whether it is dependent on natural habitat and thus requires high-yielding agriculture to reduce land requirements (i.e. sparing land for nature – “land sparing”) (Fischer *et al.*, 2014; Phalan *et al.*, 2011). But recently consensus has started to develop that convey that different strategies are needed in different contexts and for different conservation goals (Ramankutty & Rhemtulla, 2012) and that sustainable agricultural management includes both measures to increase on-farm habitat quality, as well as increasing productivity while minimizing harm to biodiversity (Clough *et al.*, 2011; Kremen, 2015; Seppelt *et al.*, 2016).

Currently, however, it appears unlikely that we will achieve either wildlife-friendly farming or stop the conversion of natural habitats by 2050 if current trends continue. Crop production is projected to increase by 50-100% by 2050 to meet future demand under current population and diet trends (Alexandratos & Bruinsma, 2012; Tallis *et al.*, 2018; Tilman *et al.*, 2011). According to a comparison of the best state-of-the-art land-use models, the combined effect of projected climate change, as well as middle of the road population and economic development projections, would result in an expansion of global cropland by about 20% by 2050 (Schmitz *et al.*, 2014). Business-as-usual trends would also result in the further conversion of >50% of natural habitats to croplands in important ecoregions like Mediterranean forests and temperate grasslands (Tallis *et al.*, 2018). In addition to this conversion of natural habitats, fertilizer use, which has large negative impacts on biodiversity and ecosystem services especially in freshwater systems, is projected to increase by 58% by 2050 (Alexandratos & Bruinsma, 2012). Wildlife-friendly farming methods are still restricted to comparatively small areas: only about 1% of global agricultural land is, for example, managed organically (Willer & Lernoud, 2017), and approximately 7.5% of it is managed with agroforestry with more than 50% tree cover (Zomer *et al.*, 2009).

Numerous analyses show, however, that achieving sustainable agriculture that produces enough food for everyone while ensuring conservation of biodiversity is possible, if far-reaching food system changes are implemented. Recent scenario analyses have shown that globally enough food could be produced for everyone in 2050 on existing agricultural land, while halting deforestation and protecting 17% of the world’s terrestrial habitats if we shifted towards more sustainable diets, reduced food waste and closed yield gaps (Erb *et al.*, 2016; Foley *et al.*, 2011; Muller *et al.*, 2017; Tallis *et al.*, 2018; West *et al.*, 2014). A recent study, for example, estimated that by closing yield gaps and optimizing where crops are grown, >50% of each of the world’s biomes could be set aside, while still producing enough food for all people in 2050 (Tallis *et al.*, 2018). Similarly, organic agriculture could be used as a wildlife-friendly agricultural management strategy, if combined with other food system strategies, e.g. reductions in food waste and changes in livestock feed composition, to provide enough food for people in 2050 on current agricultural land while also reducing pesticide use and nitrogen pollution (Muller *et al.*, 2017). These various scenarios show that both land-sharing and land-sparing strategies would be possible to help conserve biodiversity while feeding humanity if broad food system changes were implemented.

4.6.2.4 Vulnerable ecosystems (Coral Reefs) (Target 10)

"By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning."

The Global Biodiversity Outlook 4 (GBO-4), which evaluated progress towards the Aichi Biodiversity Targets in 2014, focused on the aspects related to climate change impacts on tropical coral reefs and the importance of reducing multiple pressures to minimize these impacts – and concluded that this target had been missed. Observations, experiments and models provide sound arguments for maintaining a strong priority on tropical coral reefs due to their exceptional vulnerability to climate change (IPCC, 2018). Warm-water coral reefs are one of the most biodiverse marine ecosystems in the world and provide a wide range of ecosystem services, especially to people living in tropical regions (CBD, 2014). They are also one of the most rapidly degrading ecosystems globally due to a combination of many pressures including pollution, overexploitation and ocean warming (see sections 4.2.2.2.2, **Box 4.2.3** in section 4.2.2.3.1; Butchart *et al.*, 2010; CBD, 2014; IPCC, 2018). Models and observations indicate that tropical coral reefs are exceptionally vulnerable to future ocean acidification and warming due to their very high sensitivity to these factors compared to most other systems (Bay *et al.*, 2017; Gattuso *et al.*, 2015; IPCC, 2018). Models project that there will be significant negative impacts even if the most ambitious targets of the Paris agreement of limiting global warming to 1.5°C are achieved (IPCC, 2018). For higher CO_2 emissions and warming scenarios, models project severe degradation of nearly all tropical coral reefs and the limits of natural adaptation and ecosystem management to preserve the integrity of these ecosystems will be exceeded (Bay *et al.*, 2017; Gattuso *et al.*, 2015).

Observations and models also indicate that all ecosystems are vulnerable to climate change or acidification to some extent (IPCC, 2014). Some ecosystems are projected to be particularly vulnerable because exposure to climate change is high – these include Arctic tundra and ocean ecosystems where warming is projected to be higher than elsewhere on the globe (Settele *et al.*, 2014). Other ecosystems are projected to be especially vulnerable due to their high sensitivity to climate change or acidification, and little space for adaptation – in addition to coral reefs, these include mountain terrestrial and freshwater ecosystems, tropical ecosystems, and deep oceans (section 4.2.2.2.3; Settele *et al.*, 2014). All ecosystems of the world are projected to experience changes in species composition and abundance due to species ranges shifts and modifications of ecosystem function caused by rising CO_2 and climate change (IPCC, 2014). A consensus ranking of ecosystem vulnerability to climate change is not available due to unsettled scientific debates and uncertainty in modelled impacts (e.g., Settele *et al.*, 2014).

Because there is a lack of consensus on the vulnerability of ecosystems to climate change outside of coral reefs, this target currently suffers from a lack of clarity. This target has been dubbed "Vulnerable Ecosystems" for shorthand (Aichi Passport, UNEP-WCMC) and covers "other vulnerable ecosystems", which poses problems of definition because all ecosystems are vulnerable to climate change or acidification to a greater or lesser extent (IPCC, 2014). As such, this target has been associated with a loosely related set of indicators, some very narrow and others overly broad, that are used to assess progress towards this target; for example, the Biodiversity Indicators Partnership lists the Ocean Health Index (extremely broad), Climatic impacts on European and North American birds (taxonomically and spatially restricted), Red List Index for reef-building corals (not well targeted for climate change impacts), and Cumulative Human Impacts on Marine Ecosystems (exceptionally broad) as indicators for this target.

There is strong evidence that reducing other stresses on ecosystems will generally improve the capacity of ecosystems to adapt to climate change. For tropical coral reefs, reducing nutrient loading and maintaining or reinforcing herbivorous fish populations helps reduce the competition by algae and these and other measures are projected to substantially improve the capacity of coral reefs to maintain their integrity in the face of climate change (Box 4.3.2 in section 2.2.3.1; Gattuso *et al.*, 2015; Kennedy *et al.*, 2013). Other examples include the importance of halting terrestrial habitat fragmentation and increasing connectivity between natural habitats to allow species to move so that they can track favourable climates (Imbach *et al.*, 2013).

Public policy and ecosystem management strategies for adaptation to climate change are being developed and deployed for some ecosystems. Forest managers, for example, have been very active in developing climate adaptation strategies based on projected impacts of climate change on trees, some of which depend on maintaining or reinforcing genetic and species diversity of trees and protecting ecosystem integrity (Keenan, 2017). However, not all climate change adaptation strategies for ecosystems are biodiversity friendly; for example, some forest adaptation strategies put an emphasis on the introduction of fast-growing alien tree species (Keenan, 2017). Evidence-based action plans for tropical coral reefs are in place for some reef systems, and most put an emphasis on maintaining ecosystem integrity as a key to enhancing resilience and resistance to climate change and acidification (e.g., Great Barrier Reef Climate Change Adaptation Strategy and Action Plan, see also Gattuso *et al.*, 2015; Kennedy *et al.*, 2013). Scientists are also actively exploring other strategies requiring much more active intervention such as protective sun screens, cultivation of warming adapted corals and climate geoengineering (Kwiatkowski *et al.*, 2015; van Oppen *et al.*, 2015).

These considerations suggest that future policy targets could highlight the relationships between climate change adaptation and biodiversity protection. They could include relatively broad objectives that are common to all climate adaptation strategies for ecosystems, as well as a particular emphasis on tropical coral reefs, focusing on: the vital importance of meeting the 2°C goal, and if possible the 1.5°C goal of the Paris Agreement in order for adaptation to be effective in highly vulnerable ecosystems *(new emphasis)*; the need to reduce multiple pressures on all vulnerable ecosystems, so as to improve their resistance and resilience in the face of climate change and acidification *(maintained emphasis)*; the key role of developing and implementing climate change adaptation measures for all ecosystems with a wide range of stakeholders that take into account the protection of biodiversity and emphasize the importance of nature-based adaptation strategies *(new emphasis)*; the need to develop strategies of societal response to projected inevitable changes in highly vulnerable systems *(new emphasis)*; and the special and urgent need to develop protection and adaptation measures for tropical coral reefs *(maintained emphasis).*

Models and other considerations also suggest that a more focused set of indicators would be helpful for monitoring progress towards such a target. For example, trends and projections of sea surface temperatures, ocean acidity, coral reef bleaching events, proxies of marine nutrient loading in coral reef areas, etc. are readily available from observations and models and may be much better adapted to monitoring progress towards a component focusing on tropical coral reefs than very broad indicators of ocean health or human impacts on marine ecosystems.

4.6.2.5 Protected Areas and other Effective Area-based Measures (Target 11)

"By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved [...]"

While the world may be on track to meet or exceed the numeric target of protecting globally 17% of the land and 10% of the oceans by 2020 (Chapter 3), other aspects of the target, including the global connectivity and representativity of protected areas, and their coverage of areas important for biodiversity (including Key Biodiversity Areas), have made little or no progress (Butchart *et al.*, 2015; Santini *et al.*, 2016). These aspects may be more important that numeric targets per se, as demonstrated by the evidence that if new protected areas between 2004 and 2014 had targeted unrepresented threatened vertebrates, it would have been possible to protect >30 times more threatened species for the same area or cost as the actual expansion that occurred (Venter *et al.*, 2014).

In theory, it would be possible to hit much larger numeric targets for protected areas in the future. Depending on scenarios, between 30-40% of the land would remain primary (forest or non-forest) habitat in 2050, and artificial land-use types (urban, cropland and pasture) would occupy 30-40% of the land (Hurtt *et al.*, 2011). In practice, much land is already degraded by processes that can spread globally including climate change and invasive species, thus restoration will be required in addition to protection (IPBES, 2018a).

The uneven distribution of biodiversity (Butchart *et al.*, 2015), projected expansion of human population, and regional differences in projected land-use change (Hurtt *et al.*, 2011) suggest that global percentage targets do not necessarily achieve effective biodiversity conservation. Indeed, an analysis looking at Target 11 for 2020 (Visconti *et al.*, 2015) showed that expanding protected areas to protect 17% of the land while minimizing the opportunity cost for people (i.e. by prioritizing protection of unpopulated areas) would reduce habitat available to threatened mammals. The reason is that threatened mammals occupy areas densely populated by humans, and protecting unpopulated areas displaces further land conversion in highly populated areas. In addition, climate change may change dramatically the suitability of protected areas for their native biodiversity in the future (Hole *et al.*, 2009; Loarie *et al.*, 2009). Therefore, dynamic scheduling (Wilson *et al.*, 2007) based on scenarios of climate and land-use change and allowing species to move across landscapes to track suitable habitat and climatic space should be used to translate numeric targets into allocation of protected areas in space and time (Pressey *et al.*, 2007).

4.6.2.6 Preventing Extinctions and Improving Species Conservation Status (Target 12)

"By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained."

Forecasts of species decline are blurred by several sources of uncertainty. While scenarios exist for climate change and land-use change (which can be used to derive habitat loss), for other direct drivers of species loss, including invasive species, overexploitation, disease spread, scenarios are lacking. These drivers and their impacts start being projected into the future though rarely at global scale and with wide coverage of species biodiversity, but they will interact with or add up to land use and climate change, intensifying species declines. Interactions among drivers have only partly been explored (e.g., climate and land-use change; Mantyka-Pringle *et al.*, 2015). Even projections based on the same driver can differ widely. For example, the proportion of species that is projected to go extinct based on climate change varies with model assumptions (amount of extinction debt, species' ability to disperse) and modelling technique (species-area curves: 22% extinctions; mechanistic or correlative models: 6-8% extinctions) (Urban, 2015). Uncertainty on the species' response to global change (adaptation / plasticity, dispersal, or local extinction) is also reflected in uncertainty in the scenario outcome (Rondinini & Visconti, 2015). Finally, extinctions are fundamentally stochastic events caused by extinction vortexes (Soulé, 1986), which are difficult to predict and prevent.

Despite wide uncertainty in the projections, business-as-usual scenarios produce substantially different outcomes compared to scenarios having a strong focus on sustainability typically (Alkemade *et al.*, 2009; Newbold *et al.*, 2015; Visconti *et al.*, 2016). Assuming that species can cope with climate change, sustainability scenarios can almost halt their decline due to land-use change (Rondinini & Visconti, 2015). This, in addition to the evidence that conservation action alone is insufficient (Butchart *et al.*, 2010; Hoffmann & Sgrò, 2011; Tittensor *et al.*, 2014) suggests that halting biodiversity loss for some indicators such as population size or average conservation status is within the boundaries of scenarios, provided that a mixed strategy of stepped up conservation action and societal changes is adopted. However, the stochasticity of extinctions means that even in the best-case scenario, considering the current depauperate state of biodiversity, some extinctions may still occur.

4.6.2.7 Ecosystem Restoration and Resilience (Target 15)

"By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through [,,,] restoration of at least 15 per cent of degraded ecosystems [...]"

The main issue with quantifying degradation and restoration is the lack of a clear baseline (IPBES 2018e). Several possible baselines can be chosen as a reference for restoring degraded land, including pre-modern (<10,000 years BCE), historical (typically between 300 and 50 years ago), counterfactual (how an ecosystem would look like in the absence of human pressures). For this reason, the scientific community has not been able to provide a detailed global assessment of land degradation, and different models estimate the proportion of degraded land between 7-40% (Gibbs & Salmon, 2015; Van der Esch *et al.*, 2017).

Given the uncertainty in the quantification of current land degradation, scenario analysis cannot provide strong quantitative predictions around restoration, but boundaries for restoration opportunities can be identified. According to the World Resource Institute, over 20 million km^2 of degraded tropical and temperate forests would be suitable for restoration (Laestadius *et al.*, 2011). Extending afforestation further, to non-forest biomes, would have significant negative effects on ecosystem services (Veldman *et al.*, 2015) as well as inevitably on the biodiversity adapted to these biomes. A trade-off between restoration of natural ecosystems and bioenergy production exists, since under a business-as-usual scenario, limiting warming to 2° C will require an expansion of bioenergy production to abandoned and degraded land (Dauber *et al.*, 2012; Nijsen *et al.*, 2012) to achieve negative emissions from biofuels (van Vuuren *et al.*, 2011).

4.7 DEALING WITH UNCERTAINTY, SPATIAL SCALE AND TEMPORAL SCALE ISSUES WHEN MOBILIZING SCENARIOS AND MODELS FOR DECISION-MAKING

4.7.1 Scenarios and models help prepare decision makers for uncertainty and long-term thinking

In the IPBES methodological assessment of scenarios and models, Ferrier *et al.* (2016) provide several examples of the use of scenarios and models in support of decision-making and policy. The methodological assessment highlights, in particular, the importance of matching the spatial and temporal scales of scenarios and models to the needs of the specific policy and decision context, and of identifying sources of uncertainty, communicating uncertainty in a transparent way to decision makers and providing tools to deal with uncertainty.

When these issues are dealt with appropriately, scenarios and models can help people prepare for future uncertainty, promote long-term thinking and broaden perspectives. For example, Johnson *et al.* (2016) found that reading scenarios of future land-use changes increased the willingness of a wide range of stakeholders to participate in land-use planning. Scenarios and models have also proven to be effective tools for engaging indigenous and local knowledge holders in planning management of socio-ecological systems (Ferrier *et al.*, 2016; Hartman *et al.*, 2016; Oteros-Rozas *et al.*, 2015). Ground truthing through monitoring, especially with engagement of stakeholders, is a valuable approach for reducing uncertainties (Robinson *et al.*, 2017). **Box 4.7.1** provides examples of the use of scenarios and models in support of decision-making, with a focus on the role of uncertainty and scale.

Box 4 7 1 Case studies of uncertainty and scale in decision-making using models and scenarios.

Example 1: Forest management and climate change – Forest managers are very actively using scenarios and models to develop management strategies for dealing with climate change because tree growth is very sensitive to climate and because trees generally live a long time, often more than a century, before they are harvested (Keenan, 2015). Forest managers often desire very fine spatial resolution climate projections (ca. 1 km^2) in order to make site-based management decisions, and the climate modeling community has made tremendous efforts to downscale global scale climate projections in order to meet this type of demand from a wide range of stakeholders (Giorgi *et al.*, 2009). However, downscaling introduces new sources of uncertainty that can degrade the quality of climate projections (Stefanon *et al.*, 2015) and often contribute little to improving management strategies (Keenan, 2015). Forest managers are also often presented with projections of climate impacts on trees and forests based on a single type of impact model. However, several model inter-comparisons show that different types of models – for example, correlative and mechanistic models – often give very contrasting projections of tree growth and distributions in response to future climate change (Cheaib *et al.*, 2012). High uncertainty in future global climate projections, high uncertainty in modeling impacts on trees and uncertainties introduced when downscaling climate projections have left many forest managers in a quandary about how to plan for climate change. Current recommendations focus on managing for uncertainty by employing forest management schemes that are robust under a broad range of climate and impact projections, for example by increasing resilience, by managing for higher genetic and species diversity, or by promoting natural regeneration (Cheaib *et al.*, 2012; Keenan, 2015). More importantly, there is a growing recognition that adaptive strategies for dealing with an uncertain future must be developed much more inclusively by creating partnerships between researchers from multiple disciplines, forest managers and local actors including indigenous communities in many cases (Keenan, 2015).

Example 2: Climate change and biodiversity at national and regional scales – The PARCC West Africa Project (Belle *et al.*, 2016) conducted a biodiversity risk and adaptation assessment using a combination of IPCC AR5 global scale climate projections, together with finer scaled assessments driven by higher resolution climate downscaling for five focal countries. While uncertainty in temperature projections was reduced through confirming consensus between local and global model projections, uncertainty in rainfall projections remained high in many areas, even though only one general circulation model was applied. A representative range of scenarios was used to assess risks to biodiversity especially in the context of protected area networks, and from this to design adaptation strategies and build regional capacity to enhance implementation. Multi-country efforts were integrated from local to regional scales to develop policy recommendations for climate change adaptation and management at national and regional levels.

Example 3: Participatory scenarios at local scales – Oteros-Rozas *et al.* (2015) reviewed 23 case studies of place-based participatory scenarios to assess the characteristics, strengths and weaknesses of participatory modeling. All but one study involved local communities, most included members of local governments and sixteen involved indigenous communities. Qualitative storylines in the form of drawings, or illustrations were the most common output (Figure 1), but most participatory processes also produced reports and scientific publications. Local communities were the most common primary audience, and fifteen studies had the explicit objective of informing policy or decision-making. Uncertainty was examined in sixteen of the studies, most focusing on uncertainty in drivers. Only six studies explicitly accounted for drivers or impacts at spatial scales above the local scale under consideration. The authors concluded that well-designed participatory processes enriched both local environmental management and scientific research by generating shared understanding and fostered thinking about future planning of social-ecological systems. Unfortunately, in most cases there was insufficient follow-up to determine the contribution to long-term policy or management outcomes. Numerous additional examples can also be found at the consortium of 'companion modeling' (www.commod.org).

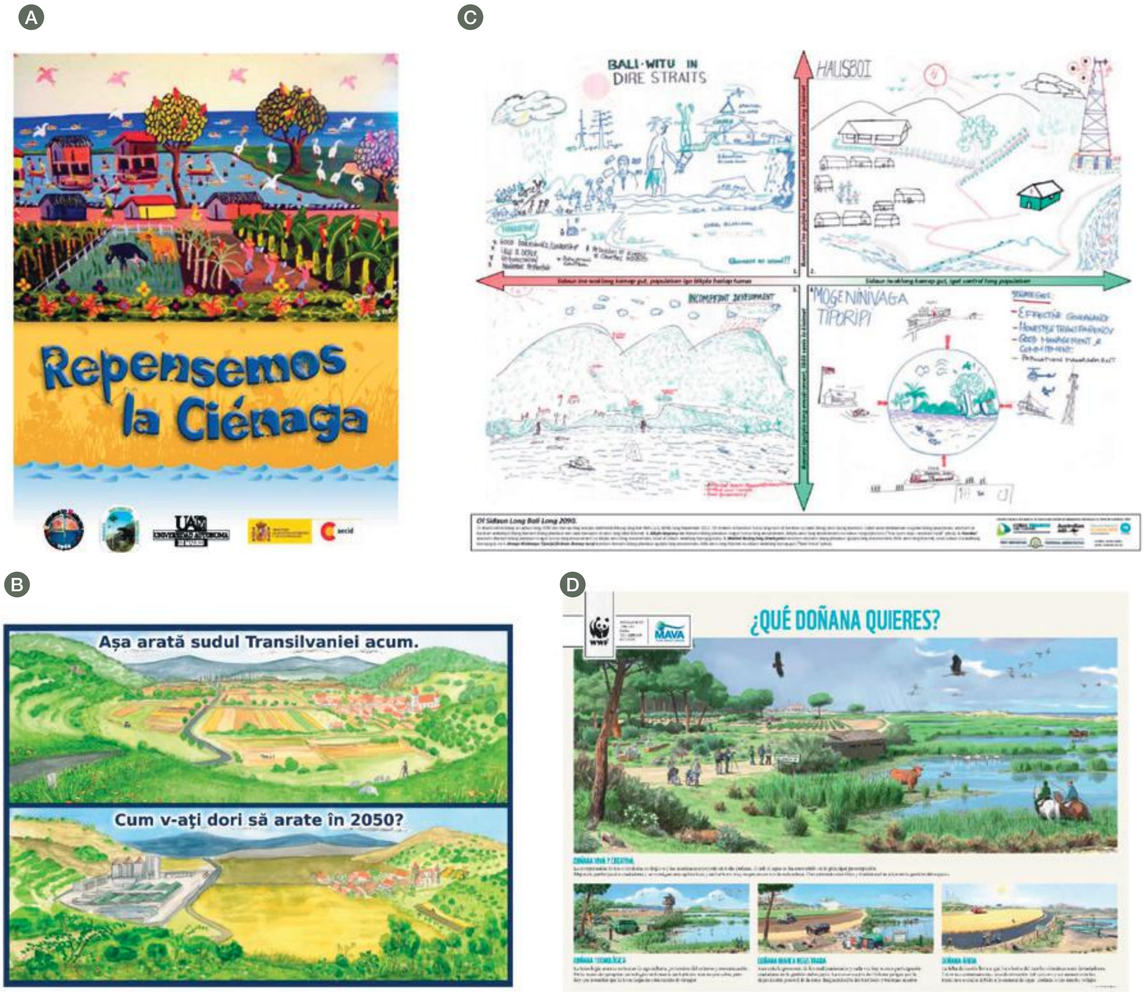


Figure 1 **Examples of outreach material used for communicating scenarios results:**

A leaflet of the Ciénaga Grande of Santa Maria case in Columbia; B postcard of the Southern Transylvania case in Romania; C poster of the drawing of the four scenarios of the Papua New Guinea case; and D poster of the socio-ecological system of Doñana Protected Area case in Spain (from Oteros-Rozas *et al.*, 2015).

4.7.2 Dealing with uncertainty when using scenarios and models to support decision-making

Uncertainty in scenarios and models arises from many sources including insufficient data for development and testing, inadequate representation of complex socio-ecological systems and intrinsically low predictability of the system being analyzed (Ferrier *et al.*, 2016). The importance of these sources of uncertainty differs greatly between scenarios of direct and indirect drivers and models of impacts on nature and NCP (Brotons *et al.*, 2016; Ferrier *et al.*, 2016). As noted in the introduction of this chapter, the exploratory scenarios assessed in this chapter can help address the high level of uncertainty in many components of direct and indirect drivers by exploring a wide range of plausible futures (Pichs-Madruga *et al.*, 2016). Evaluation of uncertainty in models of nature and NCP are typically addressed using comparisons of model outputs with data, intercomparisons of multiple types of models, sensitivity analyses and measures of error propagation in coupled models (Brotons *et al.*, 2016).

Uncertainty in scenarios and model projections is not necessarily a major obstacle to acceptance by stakeholders, especially if it does not directly conflict with their recent experiences (Kuhn & Sniezek, 1996). Indeed, despite the common perception that communication of uncertainty can lead to confusion for decision makers, recent studies show that most audiences value the communication of uncertainty in scientific evidence as opposed to oversimplification (Fischhoff & Davis, 2014; Rudiak-Gould, 2014). This highlights the importance of transparency as well as sustained, effective communication between scientists and decision makers throughout the processes of using models for decision support (Acosta *et al.*, 2016; Ferrier *et al.*, 2016). There are also a wide range of qualitative and quantitative decision support mechanisms that can help decision makers deal with uncertainty, even though these tools are underexploited in many decision-making contexts (Acosta *et al.*, 2016).

The literature survey carried out for this chapter (Appendix A4.1.1) highlights the challenges facing the scientific community in dealing with uncertainty. The majority of studies did not include an analysis of uncertainty **(Figure 4.7.2a)**. Of those that did include an analysis, most focused on uncertainty associated with different scenarios of direct and indirect drivers and less than half provided quantitative analyses of uncertainty. Relatively few studies examined multiple sources of uncertainty. This analysis shows that significant progress needs to be made in understanding, quantifying and communicating uncertainty in order for scenarios and models to be more widely used in decision-making.

In the small number of studies that have assessed uncertainty across a wide range of sources, the relative contribution of sources of uncertainty varies substantially over time, space and different measures of nature or NCP (e.g., **Figure 4.7.2b**; Payne *et al.*, 2016). These analyses also indicate that currently the largest sources of uncertainty arise from differences in model structure or application rather than data, scenarios or models of direct drivers (e.g., **Figure 4.7.2b**; Payne *et al.*, 2016). It is important to note as well that the range of scenarios typically used in many analyses may not cover plausible extremes and potential regime shifts (Leadley *et al.*, 2010; Pereira *et al.*, 2010; Prestele *et al.*, 2016).

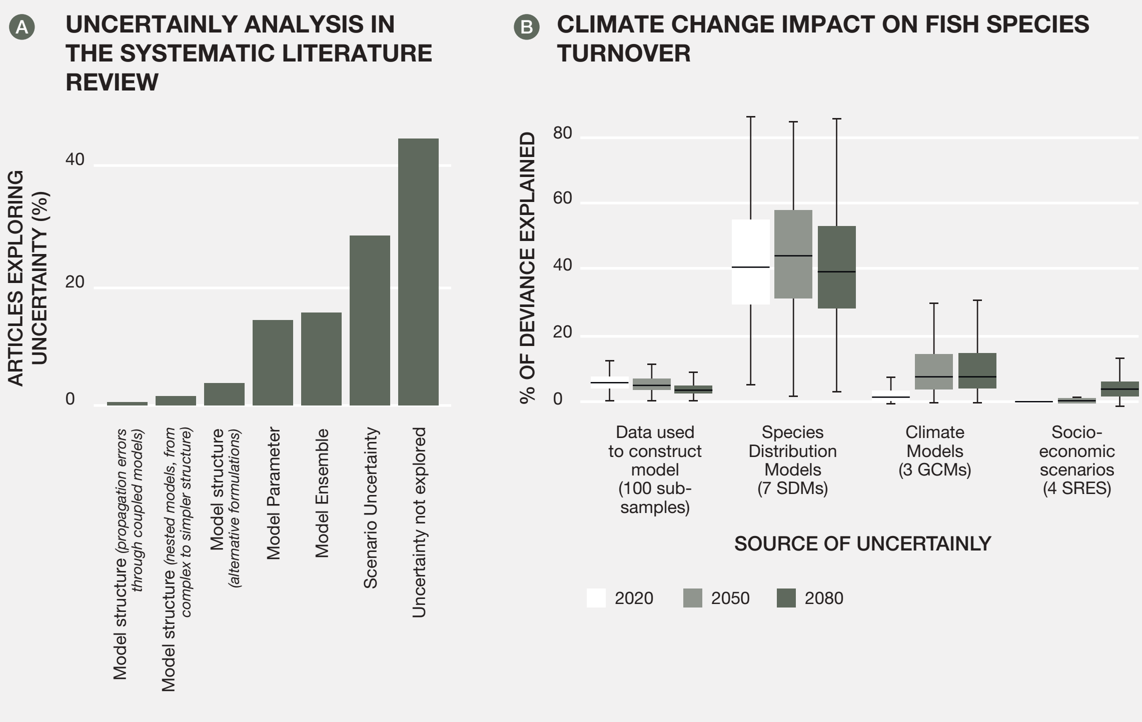


Figure 4 7 2 **Treatment and importance of different sources of uncertainty in models and scenarios of nature and NCP.**

A Outcome of the analysis of the systematic literature review (Appendix A4.1.1) showing the percentage of studies that include estimates of different sources of uncertainty. B An example of systematic analysis of sources of uncertainty in models of fish community responses to climate change (from Buisson *et al.*, 2010).

Comparisons of models and observations provide a powerful means of evaluating uncertainty in models of impacts on nature and NCP, and for communicating with decision makers. Considerable work has been done to evaluate models of ecosystem functions and some categories of NCP (e.g., ecosystem carbon stocks and fluxes; Zaehle, 2013), that indicated large variation between models, and helped improving the understanding of the capacities and limits of these models. On the other hand, models of global change impacts on species diversity, species range, habitat change and many NCP suffer from a chronic deficit of comparison with independent datasets (i.e., datasets that are entirely independent from the data used to develop and calibrate the model (Araújo & Guisan, 2006; Settele *et al.*, 2014). Those studies that have made robust comparisons between models and data indicate that agreement between models and data varies greatly between species, habitats and NCP (Araujo & Rahbek, 2006; Sitch *et al.*, 2008). It is widely acknowledged that significant progress needs to be made in comparing models and data in order for scenarios and models to be more widely used in decision-making (Araújo & Guisan, 2006; Dawson *et al.*, 2011).

There is a growing consensus that triangulation of multiple approaches, e.g., ecosystem and species models, projections based on trend extrapolation, in situ observations and experimentation, should be used to increase confidence in models (Dawson *et al.*, 2011). There are a number of efforts underway to improve international collaboration to including efforts being supported by IPBES (Rosa *et al.*, 2017; Tittensor *et al.*, 2018b).

4.7.3 The challenge of spatial and temporal scales in using scenarios and models to support decision-making

The IPBES conceptual framework emphasizes the importance of considering multiple temporal and spatial scales (e.g. local, national, regional and global scales) in understanding, assessing and managing nature and nature's contributions to people (Diaz et al 2015a, b) note that "although the biodiversity crisis is global, biodiversity distribution and its conservation status is heterogeneous across the planet; therefore, the solutions will have to be scalable to a much finer level". As such, scenarios and models used for assessments and decision support need to be developed at a wide range of spatial and temporal scales and relationships between scales need to be explicitly accounted for (Ferrier *et al.*, 2016; Rosa *et al.*, 2017).

The IPBES methodological assessment of scenarios and models highlighted the strong relationships between spatial and temporal scales, types of scenarios employed and decision-making contexts (Ferrier *et al.*, 2016; **Figure 4.7.3**). Participation of stakeholders in developing scenarios is more common and better formalized at the local scale than at regional or global ones. Local scale scenarios and models also often focus on projections over much shorter time horizons, several years to a few decades, whereas supra-national scenarios and models are often multi-decadal (Ferrier *et al.*, 2016). Local policy and decision-making more often mobilize intervention scenarios to examine policy design and implementation with the objective of providing input to decision support. At the other end of the spectrum of spatial scales, global policy and decision-making tend to rely on exploratory scenarios for agenda setting or policy review **(Figure 4.7.3)**. These relationships between spatial and temporal scale with their use within different parts of the policy cycle are important to keep in mind as a context for interpreting the analyses presented earlier in this chapter.

Explicitly accounting for linkages across spatial and temporal scales can, in some decision contexts, enhance the ability of existing scenarios and models to address the multi-scale nature of environmental policy and decision-making (Cheung *et al.*, 2016; Rosa *et al.*, 2017). For example, studies undertaken at larger scales lose the site specificity that policymakers and managers often desire. On the other hand, local case studies provide a refined understanding of local issues based on long term investigation at specific locations, but the possibility of generalizing findings is limited by the geographic coverage of the studies and the locality-specific conditions (Castella *et al.*, 2007). These are common and well-known trade-offs among precision, realism and generality one faces when constructing and analyzing models (Levins, 1966).

Existing scenarios and modeling tools and approaches typically do not capture, or poorly capture the linkages across scales, including interactions and feedbacks between them (Carpenter *et al.*, 2009; Cheung *et al.*, 2016). This is in large part due to methodological limitations that are difficult to overcome, although ambitious efforts are now addressing solutions (e.g., Purves *et al.*, 2013). The IPBES methodological assessment report on scenarios and models of biodiversity and ecosystem services explored how to address societal and ecological processes that act at multiple spatial scales, and the challenges they present for decision-making (Cheung *et al.*, 2016). Multi-scale processes can be forecasted by linking (coupling) across scales, scenarios and models developed at particular scales. This process often requires some harmonization of scenarios across spatial scales.

Harmonization across spatial scales involves upscaling (summarizing fine-scale information at coarser scale) and/or downscaling (inferring fine-scale information from coarser scale). Existing applications have greater emphasis on downscaling than upscaling. Downscaling provides information for local-scale policy making using the large

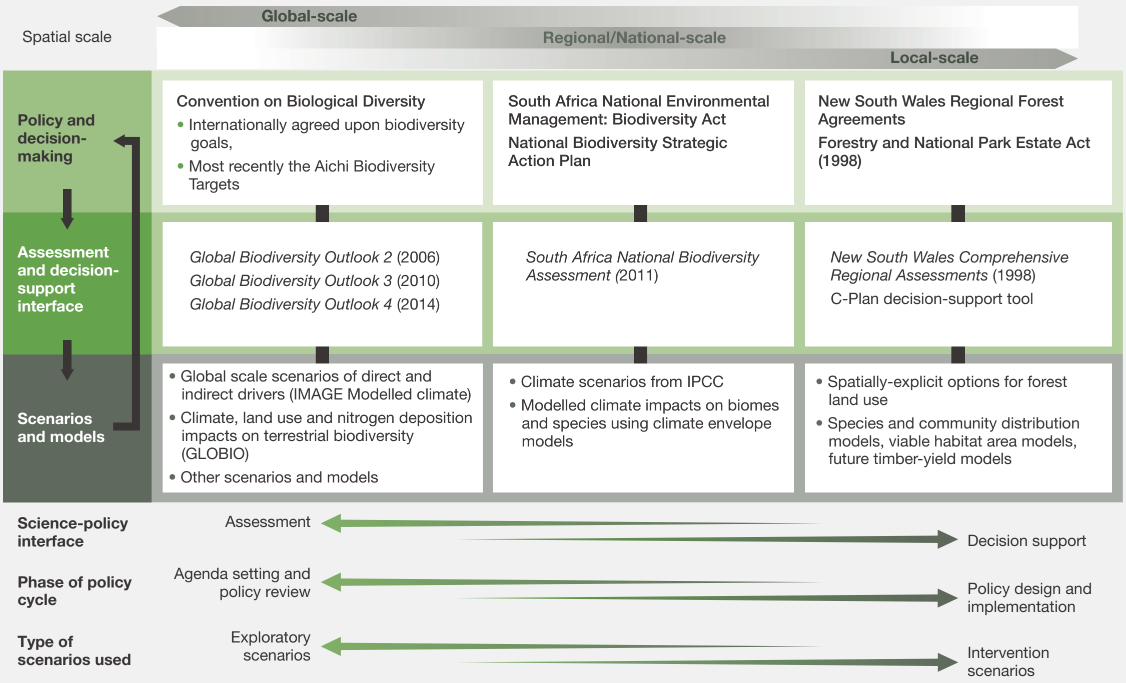


Figure 4 7 3 **Examples of the use of scenarios and models in agenda-setting, policy design and policy implementation relating to the achievement of biodiversity targets across a range of spatial scales.**

The diagram indicates the typical relationships between spatial scale (top arrows), type of science-policy interface (upper set of arrows at bottom), phase of the policy cycle (middle set of arrows at bottom) and type of scenarios used (lower set of arrows at bottom). Source: IPBES (2016b).

scale information and projections as boundary conditions and using the most refined local information to represent local processes more reliably. However, while the objective is to decrease process uncertainty at the local scale, the change of scale can introduce new sources of uncertainty, because downscaling is usually done through modelling or heuristic rules that introduce errors. Models and scenario comparison across multiple sites is another means to upscale scenarios and infer generalities, and there is a growing number of applications of this approach: Fish-Mip (Tittensor *et al.*, 2018b); IndiSeas (Fu *et al.*, 2018; Shin *et al.*, 2018); Madingley Model (Bartlett *et al.*, 2016; Harfoot *et al.*, 2014). Technical progress is being made in downscaling and upscaling, in particular by integrating data from a wide variety of sources and using powerful mathematical tools that combine spatial interpolation, upscaling, downscaling, data fusion, and data assimilation (Hoskins *et al.*, 2016; Yue *et al.*, 2016).

Despite these methodological challenges, there are substantial potential benefits of using multi-scale scenarios and models for improving understanding of system dynamics and for providing better support for decision-making. Ferrier *et al.* (2016) recommend that the scientific community works "on methods for linking […] scenarios and models across spatial and temporal scales" and in particular that IPBES works with the scientific community to "develop a flexible and adaptable suite of multi-scaled scenarios" (see also Rosa *et al.*, 2017). Approaches for developing multi-scale scenarios include using global-scale scenarios as boundary conditions for regional-scale scenarios, translating global-scale storylines into regional storylines, using standardized scenario families to independently develop scenarios across scales, and the direct use of global scenarios for regional policy contexts. These methods of upscaling can minimize inconsistencies between local scale contexts with larger scale assumptions, while also representing a diversity of local scale contexts (see Biggs *et al.*, 2007 for an example). However, substantial resources and effort are needed to coordinate the development and aggregation of multiple local scale scenarios, so it is rarely done. Of particular importance, is the post-hoc approach to scaling used in Chapter 5 of this assessment and the IPBES regional assessments that have used common (or "archetype") scenarios in order to make qualitative linkages across spatial and temporal scales (see also Biggs *et al.*, 2007; Kok & van Delden, 2009).

However, multi-scale scenarios and models are not appropriate in every decision context, particularly when error propagation increases uncertainty to an unacceptable level. When system processes interact across scales resulting

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in nonlinear dynamics, harmonizing of models and their outputs across these scales is more prone to scaling error, therefore the uncertainty resulting from model linkages should be quantified (Cheung *et al.*, 2016), but the literature survey suggests this is rarely done (see section 4.7.2).

4.7.4 Improving communication and building capacity to enhance the use of scenarios and models in decision-making

The IPBES methodological assessment of scenarios and models highlighted cases in which scenarios and models have been successfully mobilized for policy and decision-making (Ferrier *et al.*, 2016). It also, however, identified several key factors that have limited the mobilization of scenarios and models for policy and decision-making (Acosta *et al.*, 2016). Many of these factors are related to insufficient communication between scientists and decision makers and the willingness and capacity of scientists and decision makers to engage in long-term interactions but may also run into more fundamental problems such as complex political agendas that are not compatible with the transparency associated with good scientific practice (Acosta *et al.*, 2016).

The IPBES methodological assessment of scenarios and models made several recommendations for improving the use of scenarios and models in decision-making to address these deficiencies (Ferrier *et al.*, 2016). One of the most important keys is to establish and maintain interactions between policymakers, stakeholders and scientists (see also Fiske & Dupree, 2014; Scheufele, 2014). In most successful applications, this typically involves many cycles of feedback between these groups during the development and use of scenarios and models. Sustained interactions between these groups help ensure that a relationship of trust is built between modelers and decision makers, that scenarios and models are adapted to the decision-making context, and that all parties understand the capacities and limits of scenarios and models.

Human and technical capacity for scenario development and modeling needs to be enhanced in order to address these shortcomings (Lundquist *et al.*, 2016). Recommendations for capacity building include promoting of open and transparent access to scenario and modelling tools, to data required for the development and testing, and to training programs on scenarios and models for scientists and stakeholders (Biggs *et al.*, 2018; Lundquist *et al.*, 2016).

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Chapter **5.**

PATHWAYS TOWARDS A SUSTAINABLE FUTURE

IPBES GLOBAL ASSESSMENT REPORT ON BIODIVERSITY AND ECOSYSTEM SERVICES
CHAPTER 5. PATHWAYS TOWARDS A SUSTAINABLE FUTURE

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CHAPTER **5**

PATHWAYS TOWARDS A SUSTAINABLE FUTURE

EXECUTIVE SUMMARY

Current evaluations (chapters 2, 3) and most future scenarios (chapter 4) show that goals for conserving and sustainably using nature and achieving sustainability cannot be met by current trajectories, and goals for 2030 and beyond, the 2020 Aichi Biodiversity Targets, and Paris Agreement on Climate Change may only be achieved through transformative changes across economic, social, political and technological factors. This chapter examines pathways towards successfully achieving these overarching goals. Our purpose is to distil from these and broader literatures the key elements of sustainable pathways—that is, ones that at a minimum would achieve the global goals related to nature by 2050 or earlier.

This analysis was rooted in the existing scenario literature mainly at the global scale incorporating results from IPBES' regional assessments, focusing on target-seeking scenarios, sustainability-oriented exploratory scenarios, and selected policy-screening scenarios. From this scenario review and our syntheses of broader literatures related to multiple drivers and complex human-nature dynamics, we analyse interactions between multiple sectors and objectives through a **nexus approach**—that is considering interactions between diverse goals and sectors. We apply this approach via six complementary foci for achieving clusters of SDGs. This analysis revealed synergies, trade-offs and common key elements in the simultaneous achievement of clusters of SDGs, incorporating thinking across scales, domains, sectors and disciplines. Below are key findings pertaining to these.

1 The pathways to achieve global goals related to nature vary significantly across geographic contexts, with different changes needed to achieve them at all scales (e.g., local, national, regional and international) (*well established*). Sustainable pathways are flexible, within a range. These pathways imply major deviations from current trends and indicate the need for sustained efforts over decades to meet internationally-agreed objectives. Despite the diversity, there is much commonality across these pathways and the interventions to achieve them {5.1. 5.2.2 and 5.3}.

2 The first focus of our nexus approach is the challenge of feeding humanity while enhancing the conservation and sustainable use of nature (SDG 15, also considering 2, 12). Our analysis concludes that future agricultural systems could feed humanity and conserve biodiversity inclusively and equitably. Such pathways imply transformation of production (e.g., broad adoption of region-specific agroecological approaches and cross-sectoral integrated landscape and watershed management), supply chains (e.g., responsible trade, phasing out harmful subsidies), and demand sides of food systems (e.g., waste reduction, diet change) (*well established*) {5.4.2.1}. Competing uses for land, e.g., for land-based climate mitigation through bioenergy production, only exacerbate these needs {5.4.2.2}. (a) Related to **agricultural production**, the diversity of agricultural systems, from small to industrial-scale, create opportunities and challenges for transformation to sustainability. The uniformity at the heart of many agricultural systems—particularly at industrial scales—and their reliance on chemical fertilizers, pesticides and preventive use of antibiotics, triggers negative outcomes and vulnerabilities. However, across these different systems, pathways to sustainable production are emerging guided for instance by agroecological principles, landscape planning, and sustainable intensification technologies. These practices could be enhanced through well-structured regulations, incentives and subsidies, and the removal of distorting subsidies. (b) Related to **supply chains**, a few food companies are in positions of power to influence positive changes at both production and consumption ends of supply chains (such as standards, certification and moratorium agreements). This creates opportunities but also risks of co-option and inaction, which can be addressed through regulations and global governance mechanisms to check or override commercial interests in maintaining monopolies and the status quo. The same applies to agricultural input companies regarding restrictions on pesticides and chemical fertilizers considered harmful to human health and the environment. (c) Finally, **end consumers** have the potential to influence the supply chain and agricultural production through their purchases and activism, via certification and pressure on brands for transparency and particular practices {5.3.2.1}.

3 The second focus is meeting climate goals while maintaining and restoring nature and its contributions to people (SDGs 7 and 13, also considering 2 and 15). In order to meet substantial climate mitigation objectives (such as the Paris Agreement's 'well below' 2°C target), a major escalation of dedicated bioenergy plantations has been proposed, but due to its large land area, this is unlikely to be compatible with biodiversity targets (*well established*). Nevertheless, a combination of other land-based mitigation activities, such as nature restoration and improved land management, have large potential for climate mitigation with positive effects on nature and its contributions to a good quality of life, including, food and water security (*established but incomplete*). Bioenergy systems can also positively affect biodiversity, carbon storage and other ecosystem services. Economic incentives might be carefully designed to promote those bioenergy systems that minimize biodiversity losses and deliver multiple benefits. However, demand-side climate mitigation measures (e.g., reduced food waste or demand for energy and livestock products) can often be more successful in achieving multiple goals, such as greenhouse gas emission reduction, food security and biodiversity protection than bioenergy plantations. These actions imply a gradient of change in consumption and lifestyles, some of which pose challenges. {5.4.1.1, 5.3.2.2}.

4 The third focus is achieving nature conservation and restoration on land while contributing positively to human well-being (SDG 15, also considering 3). Expansion of current protected area networks—and making them ecologically effective, representative and well-connected—is central to successful pathways (*well established*). However, to accommodate conservation and restoration where land is an increasingly limited resource, extensive and proactive participatory landscape-scale spatial planning is key (*well established*). The scenarios literatures, especially at local to national scales, point out ways to further safeguard protected areas into the future, including enhancing monitoring and enforcement systems, managing biodiversity-rich land and sea beyond protected areas, addressing property rights conflicts and protecting environmental legal frameworks against the pressure of powerful interest groups (agribusiness, mining, and infrastructure). Facilitating and scaling up financing mechanisms to promote restoration and conservation within and outside protected areas are critically important, particularly in developing regions. In many areas, conservation will require building capacity and new forms of stakeholder collaboration, and removing existing barriers (e.g., unresolved land tenure, land/sea access, harmful economic incentives and policies, etc.). Also important are economic alternatives, technical assistance, well-designed payment for ecosystem services (PES) programs {5.4.2.1}, new value chains for local agricultural and biodiversity products, and better access to basic services (education, health, etc.). Indigenous Peoples and Local Communities (IPLCs) are central players, as at least one quarter of the global land area is traditionally managed, owned, used or occupied by Indigenous Peoples[1]. These areas include approximately 35 per cent of the area that is formally protected, and approximately 35 per cent of all remaining terrestrial areas with very low human intervention. Finally, well-designed innovations for the conservation-oriented economic use of biodiversity (e.g., biomimicry in pharmaceuticals, cosmetics, food) could foster conservation while benefiting local populations and regional economies {5.3.2.3}.

5 The fourth focus is maintaining freshwater for nature and humanity (SDG 6, also considering 2 and 12). Pathways exist that improve water use efficiency, increase storage and improve water quality while minimising disruption of natural flow regimes. Promising interventions include practising integrated water resource management and landscape planning across scales; protecting wetland biodiversity areas; guiding and limiting the expansion of unsustainable agriculture and mining; slowing and reversing de-vegetation of catchments; and mainstreaming practices that reduce erosion, sedimentation and pollution run-off and that minimize the negative impact of dams (*well established*). Major interventions enable achievement of these SDGs, differing across contexts. Key among these are three general changes: (a) improving freshwater management, protection and connectivity; (b) participation of a diversity of stakeholders, including Indigenous Peoples and Local Communities, in planning and management of water and land use (including protected areas and fisheries); and (c) strengthening and improving implementation and enforcement of environmental laws, regulations, and standards. Slowing and reversing deforestation of catchments is key to buffering surface and underground storage, and maintaining sediment transport regimes and water quality. Sector-specific interventions include improved water-use efficiency techniques (including in **agriculture, mining and energy)**. Freshwater biodiversity goals can be facilitated by **energy** production interventions, including scaling-up non-hydro renewable energy generation (wind, solar), transitioning to air and sea-water cooling, and judicious evaluation of hydropower developments. Increased **water storage** can be achieved through policies that implement a mix of groundwater recharge, integrated management (e.g., 'conjunctive use') of surface and groundwater, wetland conservation, low-impact

1. These data sources define land management here as the process of determining the use, development and care of land resources in a manner that fulfils material and non-material cultural needs, including livelihood activities such as hunting, fishing, gathering, resource harvesting, pastoralism, and small-scale agriculture and horticulture.

dams, decentralized (for example, household-based) rainwater collection, and locally developed water conservation techniques (such as those developed by Indigenous Peoples and Local Communities) and water pricing and incentive programmes (such as water accounts and payment for ecosystem services programmes). Balancing competing human and environmental demands for water entails improved recognition of the different values of the resource (e.g., via water accounts, payment for ecosystem services programs, etc.), and improved governance systems inclusive of diverse stakeholders. Pricing policies that respect the human right to safe drinking water are important to manage **water consumption and reduce waste and pollution**. Further investments in infrastructure are important, especially in developing countries, undertaken in a way that considers ecological function and the careful blending of built with natural infrastructure {5.3.2.4}.

6 **The fifth focus is harmonizing food provision and biodiversity protection in the oceans (SDG 14, also considering 2, 12). Successful pathways include the effective implementation and expansion of marine protected areas and ecosystem-based fisheries management, with spatial planning and targeted restrictions on catches or fishing effort (*well established*).** Achieving biodiversity and food security goals in marine ecosystems will involve close attention to their synergies and trade-offs. In particular, safeguarding and improving the status of biodiversity will often entail reducing the negative effects of fish harvest and aquaculture, potentially resulting in near-term losses in access to living marine resources. There is also complementarity between biodiversity and food provision, however meeting food security goals will often involve promoting the conservation and/or restoration of marine ecosystems including through rebuilding overfished stocks; preventing, deterring and eliminating illegal, unreported and unregulated fishing; encouraging ecosystem-based fisheries management; and controlling pollution through removal of derelict gear and addressing plastics. Some of the trade-offs between food provision and biodiversity projection can be managed or avoided through appropriate social participation and community engagement in decision-making and implementation. Sustainable pathways also entail addressing growing problems with many marine pollutants—particularly those prone to bioaccumulation—which both affect marine ecosystems and undermine seafood safety and human health. Similarly, attaining sustainable pathways will be more feasible given stronger greenhouse gas reductions, which should lessen trade-offs between biodiversity and food provision. Thus, pathways to sustainable ocean development involve addressing multiple human stressors {5.3.2.5}.

7 **The sixth focus is sustaining cities while maintaining the underpinning ecosystems (both local and regional) and their biodiversity (SDG 11, also 15). Successful pathways generally entail integrated city-specific and landscape-level planning for retaining species and ecosystem in cities and surrounding regions, as well as limits on urban transformation. These can be achieved by strengthening local- and landscape-level governance and enabling transdisciplinary planning to bridge sectors and departments, and to engage businesses and other organizations in protecting public goods (*well established*).** Because many aspects of life within cities are underpinned by nature, achieving these goals is important not only for global biodiversity but also for local human quality of life. Opportunities to integrate ecological and built infrastructure are increasingly important, particularly for cities in developing countries with high deficits of infrastructure. Maintaining and designing for ecological connectivity within urban space is critical for nature and people, especially in large cities. Particularly important at the regional scale are policies and programmes that promote sustainability-minded collective action protect watersheds beyond city jurisdiction and ensure the connectivity of ecosystems and habitat (e.g., through green-belts), and that city expansion towards key regional biodiversity sites does not undermine their conservation mandates. Sustaining nature's contributions to people—for current and future needs—implies integrating these considerations into planning and development of infrastructure investments. Specifically, this includes encouraging—at all scales—compact communities, underlying road network designs, and sustainable transportation systems (including active, public and shared transport), which enable low-carbon and low-resource lifestyles throughout the decades or centuries over which this infrastructure will persist {5.3.2.6}.

8 **The cross-scale nexus analysis reinforced the importance of including regional and local perspectives in global pathways to sustainability.** Global scenarios alone do not capture some difficulties and unintended consequences of implementing certain measures at regional and local levels. Key constituents of regionally sensitive global pathways include (a) substantially bolstering monitoring and enforcement systems, which are especially weak in developing nations; and (b) enabling locally tailored choices about consumption and production, accounting for poverty, inequality and cultural variability.

9 **The analysis based on the nexus approach suggests several common constituents of sustainable pathways that contribute to the achievement of seven nature-based Sustainable Development Goals (SDGs 2, 3, 6, 11, 13, 14 and 15).** These key constituents include (a) safeguarding remaining natural habitats on land and sea by strengthening, consolidating, expanding and effectively

managing protected areas and their integration with surrounding land uses (*well established*), (b) undertaking large-scale restoration of degraded habitats (*well established*), and (c) integrating these activities with development through sustainable planning and management of landscapes and seascapes so that they contribute to meet human needs including food, fibre, water and energy security, while continually reducing pressure on natural habitats (*well established*) {5.3.3}.

10 **These SDG outcomes can be achieved through complementary top-down and bottom-up action on eight priority points of intervention (leverage points) and employment of five governance mechanisms (levers) {5.3.3, 5.4} (Figure 5.1).** Supplementing with additional analysis from social sciences and other literature on transformative change and human-nature relationships suggests that these leverage points and levers may be non-substitutably important. Leverage points can be engaged via a range of different mechanisms, including the five levers and more.

11 **Five main interventions ("levers") can generate transformative change to address the indirect drivers that are the root causes of nature deterioration: (1) incentives and capacity-building; (2) cross-sectoral cooperation; (3) pre-emptive action; (4) decision-making in the context of resilience and uncertainty; and (5) environmental law and implementation.** Employing these levers involves the following, in turn: (1) developing incentives and widespread capacity for environmental responsibility and eliminating perverse incentives; (2) reforming sectoral and segmented decision-making to promote integration across sectors and jurisdictions; (3) taking pre-emptive and precautionary actions in regulatory and management institutions and businesses to avoid, mitigate and remedy the deterioration of nature, and monitoring their outcomes; (4) managing for resilient social and ecological systems in the face of uncertainty and complexity to deliver decisions that are robust in a wide range of scenarios; and (5) strengthening environmental laws and policies and their implementation, and the rule of law more generally. All five levers may require

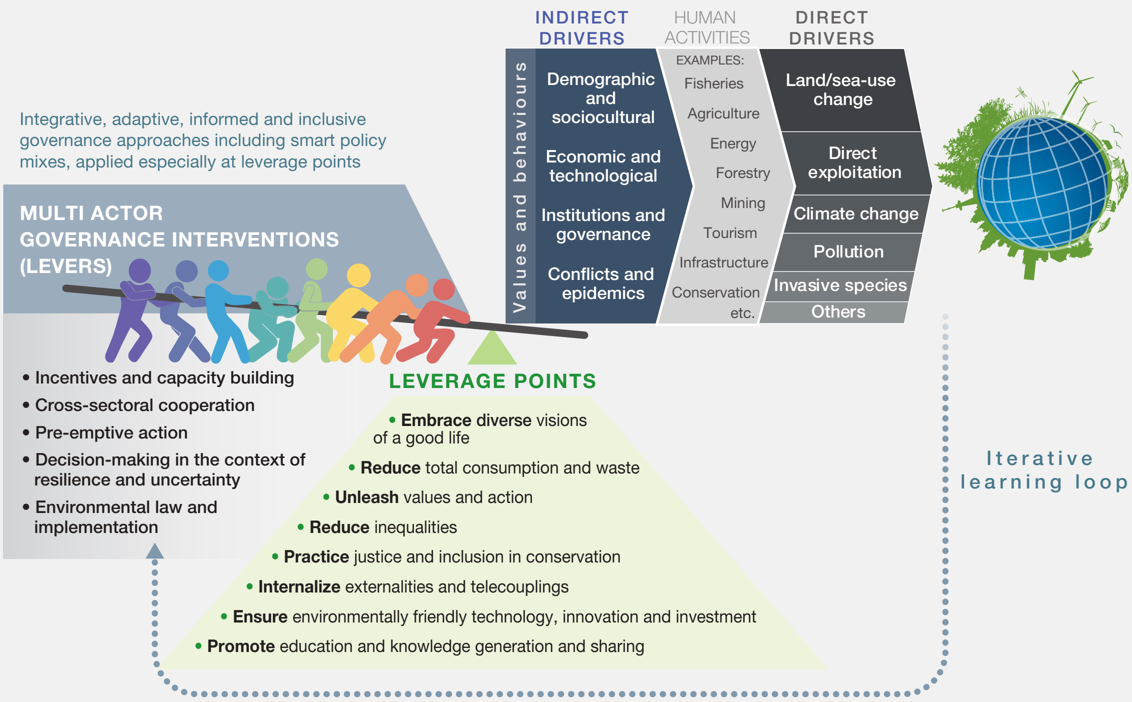

Figure 5 1 **Transformative change in global sustainability pathways.**

Collaborative implementation of priority governance interventions (levers) targeting key points of intervention (leverage points) could enable transformative change from current trends towards more sustainable ones. Most levers can be applied at multiple leverage points by a range of actors, such as intergovernmental organizations, governments, non-governmental organizations, citizen and community groups, Indigenous Peoples and Local Communities, donor agencies, science and educational organizations, and the private sector, depending on the context. Implementing existing and new instruments through place-based governance interventions that are integrative, informed, inclusive and adaptive, using strategic policy mixes and learning from feedback, could enable global transformation.

new resources, particularly in low-capacity contexts such as in many developing countries.

12 **The first two points of leverage are enabling visions of a good quality of life that do not entail ever-increasing material consumption (including due to population growth and waste), and lowering total consumption and waste, including by addressing both population growth and per capita consumption differently in different contexts.** Whereas the ability to increase consumption is key to improve human quality of life in some regions and countries, in more-developed contexts human quality of life can be enhanced with decreasing overconsumption and waste (*well established)* {5.4.1.1}. Such changes in consumption may be achieved by fostering existing alternative visions of a good quality of life (*well established)* {5.4.1.2}.

13 **The third leverage point is unleashing existing widely held values of responsibility to effect new social norms for sustainability, especially by extending notions of responsibility to include impacts associated with consumption.** Such norm changes require concerted effort but are feasible when infrastructure and institutions (including social arrangements, regulations and incentives) activate values held by individuals (*well established*) {5.4.1.3}. Diverse values are consistent with sustainable trajectories, but not all have received equal attention in global sustainability discourses.

14 **Leverage is also found in addressing inequalities, especially regarding income and gender, which undermine capacity for sustainability and ensuring inclusive decision-making, fair and equitable sharing of benefits arising from the use of and adherence to human rights in conservation decisions. Inequalities tend to reflect and can cause excessive use of resources (*established but incomplete*), and appropriate inclusion of Indigenous Peoples and Local Communities is central to justice and sustainable protection of nature (*well established)* {5.4.1.4, 5.4.1.5}.** Full and effective participation of Indigenous Peoples and Local Communities is important and would contribute to conservation, restoration and management of the extensive areas of land and water over which they retain rights or control (*well established*) {5.4.1.5}.

15 **Crucial but often-overlooked points of leverage are accounting for nature deterioration from local economic activities and socioeconomic-environmental interactions, including externalities, over distances (telecouplings) into public and private decision-making, such that technological and social innovation and investment regimes all work for—rather than against—nature and sustainability, taking into account potential rebound effects. These leverage points are central to a global sustainable economy.** Whereas existing environmental policies and international trade have often reduced negative impacts in a specific place, many have had unintended spillover effects elsewhere (*well established)* {5.4.1.6}. More important in this context than valuation is to actually reflect these costs in economic decision-making (via required payments for mitigating damages), which can be initiated by private or public actors. Similarly, technological innovations are ambivalent in their impact on biodiversity (*well established)* (5.4.1.7). Regulations and non-governmental governance mechanisms including standards and certification can ensure that innovation and investment have positive effects at the global scale, which is key to global sustainable economies and sustainable pathways (*well established)* {5.4.1.6 and 5.4.1.7}.

16 **Transformations towards sustainability are more likely when efforts are directed at the following key leverage points, where efforts yield exceptionally large effects (Figure SPM.9): (1) visions of a good life; (2) total consumption and waste; (3) values and action; (4) inequalities; (5) justice and inclusion in conservation; (6) externalities and telecouplings; (7) technology, innovation and investment; and (8) education and knowledge generation and sharing.** Specifically, the following changes are mutually reinforcing: (1) enabling visions of a good quality of life that do not entail ever-increasing material consumption; (2) lowering total consumption and waste, including by addressing both population growth and per capita consumption differently in different contexts; (3) unleashing existing widely held values of responsibility to effect new social norms for sustainability, especially by extending notions of responsibility to include impacts associated with consumption; (4) addressing inequalities, especially regarding income and gender, which undermine capacity for sustainability; (5) ensuring inclusive decision-making, fair and equitable sharing of benefits arising from the use of and adherence to human rights in conservation decisions; (6) accounting for nature deterioration from local economic activities and socioeconomic-environmental interactions over distances (telecouplings), including, for example, international trade; (7) ensuring environmentally friendly technological and social innovation, taking into account potential rebound effects and investment regimes; and (8) promoting education, knowledge generation and maintenance of different knowledge systems, including the sciences and indigenous and local knowledge regarding nature, conservation and its sustainable use.

17 **The eighth point of intervention is promoting education, knowledge generation and maintenance of different knowledge systems, including the sciences and indigenous and local knowledge regarding nature, conservation and its sustainable use. These elements**

are especially important in the face of demographic processes increasing the 'distance' between urbanizing populations and nature. Education generally only fosters changes in consumption, attitudes and relational values conducive to sustainability when it builds on existing understandings, enhances social learning, and embraces a "whole person" approach (*well established)* {5.4.1.8}. Whereas Indigenous Peoples and Local Communities have or had various traditional practices and/or norms that enabled sustainable use of local resources, communities worldwide are facing loss of knowledge transmission along with changes in values and lifestyles. Achieving sustainability from local to global levels will benefit from multiple strategies for education and learning, from recognizing and promoting local environmental knowledge and sustainable practices to integration throughout school curricula (*well established)* {5.4.1.5 and 5.4.1.8}.

18 **Applicable across many intervention points, the first lever is developing incentives and widespread capacity for environmental responsibility. Important actions would often include eliminating perverse subsidies and improving fairness in regulations and incentive programs at every scale (*well established*) {5.4.2.1}.** Whereas many incentive programs are designed in ways that may undermine stewardship and responsibility-taking (*well established)*, there appears to be great scope for subtle changes to policies and programs to instead reinforce commitment with such relational values (*established but incomplete)* {5.4.1.3 and 5.4.2.1}.

19 **Three levers pertain to management and governance institutions. These are reforming business and economic, political and community structures to enable decision-making that (2) promotes integration across sectors and jurisdictions, (3) takes pre-emptive and precautionary actions in regulatory and management institutions and businesses to avoid, mitigate and remedy the deterioration of nature, also monitoring these outcomes, and (4) manage for resilient social and ecological systems in the face of uncertainty and complexity to deliver decisions that are robust in a wide range of scenarios.** Whereas many resources are managed separately with only limited capacity to account for interactions between resources in social-ecological systems, management that integrates more fully across sectors and jurisdictions appears to be central to achieving global sustainability goals (*well established*) {5.4.2.2}. Most resource management and environmental assessment approaches are reactionary, generally enforcing regulations after damage occurs, rather than anticipating it, despite the latter being more suitable for sustainable trajectories (*well established*) {5.4.2.3}. Finally, achieving global goals entails avoiding undesirable collapses of resource systems and restoring underperforming degraded systems, both of which follow from governance for resilience and adaptation (*well established*) {5.4.1.4, 5.4.2.3 and 5.4.2.4}.

20 **The final underlying key intervention that emerges is strengthening environmental laws and policies and their implementation, and the rule of law more generally as a vital prerequisite to reducing biodiversity loss and human and ecosystem health (*well established*). This includes not only strengthening domestic laws but also international environmental laws and policies**, including mechanisms to both harness and rein in the power of business**.** Stronger international laws, constitutions, and domestic environmental law and policy frameworks, as well as improved implementation and enforcement of these rules, are critical in protecting biodiversity and nature's contributions to people (*well established)* {5.4.2.5}.

21 **Although these various changes may seem insurmountable when approached separately, each enabling intervention removes barriers associated with implementing others (*well established*) {5.4.3}. Accordingly and perhaps counter-intuitively, multiple interventions can be achieved more feasibly than individual ones (*well established*) {5.4.3.1}. Governments, businesses, and civil society organizations have many opportunities to boost ongoing processes and to initiate new ones that collectively constitute transformative change (*well established*) {5.4.3.2}.** The most important of these may involve laying the groundwork for changes to leverage points {5.4.1} and levers {5.4.2} at the root of environmental degradation or its reversal, by reducing opposition and obstacles, including those with interests vested in the status quo, but such opposition can be overcome for the broader public good {5.4.3.2}. Chapter 6 further details these challenges and also the opportunities and options for overcoming them, achieving long-term transformational change by initiating short-term measures today.

5.1 INTRODUCTION

While nature and its contributions to people are on a deeply unsustainable trajectory (c.f. chapters 2, 3, and 4), there is a multitude of voices demanding fundamental changes in the global socioeconomic structure and action. To change course toward a sustainable future, numerous organizations and individuals have called for actions at least since the 1980s (e.g., Our Common Future report, Agenda 21, The Future We Want). In response to the calls, many sustainability goals and targets have been set across local to global levels, including Aichi Biodiversity Targets and the 2030 United Nations Sustainable Development Goals (SDGs). Efforts around the world are under way for transformation to sustainability (CBD's Vision for Biodiversity 2050, Bennett *et al.*, 2016). Unlike the Intergovernmental Panel on Climate Change (IPCC), which has clear and single targets and timelines, single targets have limited capacity to address biodiversity declines. While proposals for using a combination of existing metrics exist (e.g., Red List index, Living Planet Index, Biodiversity Intactness Index) (Mace *et al.*, 2018), IPBES' work is guided by these and other existing targets including the Aichi Biodiversity Targets and the SDGs, which represent the closest option for an overall policy target for both ecosystems and human well-being.

In-depth understanding of the past trajectories and the current status of the global coupled human and natural system provides some useful knowledge needed to develop and employ models for a sustainable future (chapter 2; MA, 2005; Pimm *et al.*, 2014). Recent rapid and unprecedented changes, however, mean that historical trajectories may serve us very poorly. Therefore, forward-looking, scenario approaches are required that take those changes into account. Chapter 4 established that most trajectories rooted in current and past trends will fail to meet the full suite of Aichi Targets and biodiversity-relevant SDGs. However, chapter 4 also explored sustainability-oriented scenarios showing that positive futures are possible and failure is not inevitable. This indicates that it may not be too late to meet those goals and targets if bold systemic and incremental changes are made.

Change towards sustainability must be profound, systemic, strategic, and reflexive. Many signs of those changes are already starting to emerge, such as encapsulated in the notion of 'seeds of the good Anthropocene' (i.e., hopeful social-ecological practices ("seeds") that could catalyse and expand (grow) to produce more desirable futures, from addressing situations of social precariousness and vulnerability to recovering habitats for water protection and/or to conserve icons like the giant pandas (Bennett *et al.*, 2016; SFA, 2015; Yang *et al.*, 2017). The key implication of current scenario projections (chapter 4) is that successful change will not happen easily or spontaneously. It will likely require a broad and intense effort, informed by the best available understanding of local to global coupled human and natural systems dynamics. Most of the models and scenarios developed so far (chapter 4) have not been built, intended or applied in ways that address profound and systemic changes.

This finding from chapter 4 has bearing on chapter 5's position on sustainability transitions—as reformist, revolutionary, or reconfigurational (Geels *et al.*, 2015). A reformist position sees sustainability as the outcome of incremental changes and constant improvement of a current system. In contrast, revolutionary positions see sustainability as requiring a radical break with current trajectories. Finally, a reconfigurational position is something in between, involving context-related transformation of everyday practices and their structural embeddings. In this chapter we are philosophically ambivalent about these positions, but the chapter 4 finding suggests that a reformist position is likely to fail to achieve some relevant SDGs or Aichi Targets.

There is no single way to transform towards sustainability, and transformations will play out differently in different places (e.g., Arctic, Antarctic, temperate, tropical regions). The analysis in this chapter highlights possible pathways for transformative change to achieve widely agreed upon sustainability goals. It also identifies key leverage points (where a small change in one factor can generate bigger changes in other factors) (Abson *et al.*, 2017; Meadows, 1999) and 'levers' of change (promising management and governance interventions), without which successful transformation would not be possible. While we use the notion of 'levers' and 'leverage points' metaphorically, recognizing that global systems—as complex social-ecological systems—cannot be manipulated as neatly as can a boulder with a stick, it helps us to clarify our intentions.

What are those pathways, points of intervention and key levers or enabling interventions? In this chapter, we seek to answer this question, both for particular important objectives as well as their connections to other objectives within the larger system. We apply the 'nexus' concept to highlight connections representing stark synergies and trade-offs between different sectors and different goals, such as producing food or mitigating climate or producing energy while conserving biodiversity, resource use options, and ecosystem functioning (Liu *et al.*, 2018).

Two kinds of information are central for this chapter: existing scenarios and broader literatures pertinent to sustainability transformations. First, there are two relevant types of scenarios (target-seeking and policy-screening) that are constructed explicitly to achieve sustainability of Aichi

Targets and biodiversity-relevant SDGs. We interpret target-seeking scenarios as alternative pathways to meet one or multiple specific goals. As there are relatively few examples of such studies, we will also examine sustainability-oriented exploratory scenarios as a proxy. Assessing all these scenarios and pathways helps to explicitly analyse assumptions (e.g., economic, political, demographic, ecological, technological, ideological), pinpoint problems of spatial and temporal scales, and identify some complexities such as nonlinearities and regional differences (IPBES, 2016). Although the analysis is global, it builds on the IPBES regional assessments and meta-analyses of local studies in the literature. Particular emphasis is given to local participatory scenarios (e.g., participatory target-seeking scenarios for social transformation and empowerment) to illustrate and deepen the understanding of how global processes play out on a local scale. This is particularly important for biodiversity assessments, and with the emphasis on indigenous and local knowledge (ILK) and practices we anticipate innovative work on exploring alternative pathways at various scales. A second source of insight is necessary, however, because such scenarios represent only a narrow slice of the literature and a subset of the factors more easily rendered in models (e.g., only partly representing ILK), it is necessary to consult a broad range of literatures on societal and biodiversity change, including a burgeoning literature on pathways and transformative change.

In this chapter, we assess these various sources and distil from them alternative pathways for the transformations needed to achieve biodiversity objectives, the SDGs, to limit global temperature increase to 1.5 degrees Celsius above pre-industrial levels (i.e. The Paris Agreement of the UNFCCC) and to mitigate emerging and existing disaster risks (e.g., the Sendai Framework for Disaster Risk Reduction). We also draw upon policy- and management-screening scenarios, and their potential to simultaneously achieve multiple (sometimes conflicting) goals. This chapter culminates in key lessons for achieving multiple biodiversity and ecosystem service goals in the form of the 'leverage points' and 'levers' that offer unparalleled opportunities for changing unsustainable structures in today's economies and societies.

In the following sections, Section 5.2 provides a conceptual orientation for our approach and explains the methods for our analysis. Section 5.3 summarizes the results of the scenario assessment in the form of a cross-scale analysis of a nexus analysis with six cross-sector foci. Section 5.4 synthesizes insights from the scenario analysis and broader literatures, from which we have identified eight points of intervention ('leverage points') and five key enabling interventions ('levers') for sustainability. Finally, Section 5.5 provides general concluding remarks.

5.2 METHODS OF ASSESSMENT

5.2.1 Conceptual Framework for Assessing Transformation

5.2.1.1 Change towards sustainability requires addressing root causes, implying fundamental changes in society

The society/nature interface can be described in various ways (see for example Descola, 2013; Haraway, 1989; Jetzkowitz, 2019; Latour, 2004; Mol & Spaargaren, 2006; Takeuchi *et al.*, 2016; for further references to ILK-related concepts of the society-nature nexus see chapter 2 and IPBES, 2018). Here we follow IPBES' conceptual framework assuming that institutions, governance systems and other indirect drivers are "the root causes of the direct anthropogenic drivers that affect nature" (Díaz *et al.*, 2015; also see chapter 1). These root causes also affect all other elements of the society/nature interface, including interactions between nature and anthropogenic assets in the co-production of nature's contributions to people (Díaz *et al.*, 2015) In addition to the conceptual framework, we adopt systems thinking because it allows (1) the combination of biophysical and societal understanding of processes, which helps to identify seeds for change, and (2) the combination of results from quantitative and qualitative scenarios and other pertinent literature.

5.2.1.2 Conceptual frameworks addressing transformative change

Various approaches currently discussed in sustainability science address the question of how profound, systemic, and strategic-reflexive changes toward (more) sustainability can be initiated. Our selection of five approaches—complexity theory and the identification of layers of transformation and leverage points, resilience thinking, the multi-level perspective on transformative change, the systems of innovation approach and initiative-based learning—comprises those we identify as widely consistent with the IPBES conceptual framework and mandate. They provide useful concepts for the integration of knowledge on pathways towards a (more) sustainable future and facilitate our imagination throughout the whole chapter.

Complexity theory and leverage points of transformation

Complexity theory attempts to untangle emergent processes in coupled human and natural systems (Liu *et al.*, 2007; Nguyen & Bosch, 2013). It stresses the importance of specific contexts and interdependent influences among various components of systems, which may result in path dependency and multi-causality, where most patterns are products of several processes operating at multiple scales (Levin, 1992). One of the implications of such interdependence is that small actions can lead to big changes (Meadows, 1999), i.e., processes can be nonlinear (Levin, 1998; Levin *et al.*, 2013). These impactful actions are considered *leverage points* because they can produce outcomes that are disproportionate large relative to initial inputs (UNEP, 2012). Although identifying and implementing such leverage points is not easy, the results can be profound and lasting (Meadows, 1999).

Resilience, adaptability and transformability in social-ecological systems

In the context of pathways involving nature and people, changes are bounded not only by technological and social feasibility, but also by spatial and ecological characteristics. *Resilience* thinking enhances our systemic understanding by putting three aspects of social-ecological systems at the center: persistence, adaptability and transformability (Folke, 2016). Resilience refers to the capacity of a system—such as a village, country or ecosystem—to adapt to change, deal with surprise, and retain its basic function and structure (Berkes *et al.*, 1998; Nelson *et al.*, 2007). Adaptability—a component of resilience—represents the capacity to adjust responses to changing external drivers and internal processes, and thereby channel development along a preferred trajectory in what is called a stability domain (Walker *et al.*, 2004). Transformability is the capacity to cross thresholds, enter new development trajectories, abandon unsustainable actions and chart better pathways to established targets (Folke *et al.*, 2010).

A multi-level perspective for transformative change

Complementary to the perspectives above, the *multi-level perspective* sees pathways as an outcome of coupled processes on three levels—niches, regimes and landscapes (Geels, 2002). At the micro level, *niches* are the safe spaces where radical innovations are possible but localized. For innovations to spread to the meso level (*regimes*—interlinked actors and established practices, including skills and corporate cultures), they must overcome incumbent actors who benefit from the status quo. Regimes can either steer for incremental improvement along a trajectory or can affect change in the *landscape* (which includes factors like cultural values, institutional arrangements, social pressures, and broad economic trends). Change at this macro (landscape) level generally involves a cascade of changes, which also affect the regime itself. The multi-level perspective has been particularly useful in understanding socio-technical pathways, which tend to be nested and interdependent across levels. It raises strategic and reflexive questions—for instance, How can we identify actions that yield structural change from individual and local to societal levels, identifying and avoiding blockages and supporting transformations towards sustainability?

System innovations and their dynamics

The *system innovation* (or ‘systems of innovation’) approach provides a framework for policy interventions to address not only single market failures, but also interconnected challenges through a combination of market mechanisms and policy tools (e.g. OECD, 2015). This approach emphasizes that system innovation generally requires a fundamentally different knowledge base and technical capabilities that either disrupt existing competencies and technologies or complement them. As technology innovation proceeds, it also involves changes in consumer practices and markets, infrastructure, skills, policy and culture (Smits *et al.*, 2010). A key component of innovation for sustainability is thus supportive business models (Abdelkafi & Täuscher, 2016; Bocken *et al.*, 2014; Schaltegger *et al.*, 2012; Seroka-Stolka *et al.*, 2017). Governments also have a role in supporting transitions, however, which extends beyond orchestrating and coordinating policies and requires an active management of transformative change, especially sequencing of policies with the different stages of the transition (Huber, 2008; Mol *et al.*, 2009; Seroka-Stolka *et al.*, 2017).

Learning sustainability through ‘real world experiments’

Several strands of research take an approach of so-called *real world experiments* (Gross & Krohn, 2005). These action research approaches emphasize how local and regional initiatives can foster shared values among diverse societal actors (Hajer, 2011), accelerating adoption of pathways to sustainability (Geels *et al.*, 2016). These experimental approaches contribute to niche innovations that are able to challenge existing unsustainable pathways and the regimes that maintain them. Bennett *et al.* (2016) suggest that emphasizing hopeful elements of existing practice offers the opportunity to: (1) understand the values (guiding principles) and features that constitute transformative change (referred to by the authors as the Good Anthropocene), (2) determine the processes that lead to the emergence and growth of initiatives that fundamentally change human-environmental relationships, and (3) generate creative, bottom-up scenarios that feature well-articulated pathways toward a more positive future (see also chapter 2.1). In the multi-scale scenario analysis applied in this chapter, local scenarios may be most closely connected to this approach.

Synthesis

The above conceptual approaches converge on the idea that profound changes in global socioeconomic systems towards sustainability occur as transformation of nested and interlinked structures and processes across various scales. In line with *systems of innovation* approaches, *resilience thinking* and the *multi-level perspective*, we consider profound changes as structural changes. However, these changes do not happen without activating impulses of individuals, groups and organisations. Accordingly, our methods for identifying pathways for sustainable futures includes two key elements: structural analyses of alternative pathways; and cross-cutting analyses of entry points for change ('leverage points') and enabling interventions for transformations ('levers').

5.2.2 Scenarios and Pathways

This chapter mobilises two complementary types of information: scenario and pathway analysis (section 5.3) and knowledge on transformative change (section 5.4). Scenario approaches help open up thinking about the future through qualitative, storytelling approaches and through quantitative systems modelling. These approaches allow for consistent analysis of complex systems and help identify consequences of changes (e.g., technological changes, changing behaviour, alternative management regimes for natural resources). At the same time, classical model-based scenario analyses often oversimplify social realities and have little detail regarding actors, behaviours and policy implementation. Socio-technical and social-ecological pathways analysis gives much more attention to different actors and actions and to finding entry points and levers towards changing pathways. Unfortunately, these approaches often lack a forward-looking perspective (they are generally retrospective) (Turnheim *et al.*, 2015). However, taken together with cross-cutting literatures on transformative change, they can bring a much needed multi-disciplinary perspective to identify and govern pathways for transformative change.

The terms **scenarios** and **pathways** are often used interchangeably especially by the global climate and integrated assessment modeling communities (Rosenbloom, 2017; Turnheim *et al.*, 2015). Here we distinguish the two concepts. **Scenarios** are plausible stories about how the future may unfold that can be told in words, numbers, illustrations, and/or maps—often combining quantitative and qualitative elements. Scenarios are not predictions about the future; rather they are possibilities used in situations of large uncertainty, based on specified, internally consistent sets of underlying assumptions (IPBES, 2016; Raskin, 2005). The global modelling community sometimes uses the term **pathway** to describe the *clear temporal evolution of specific scenario aspects or goal-oriented scenarios* (see **Boxes 5.1-3**). The concept of **pathways** in our chapter includes—but is not limited to—this meaning. More broadly, we consider pathways as "*alternative trajectories of intervention and change, supported by narratives, entwined with politics and power*" (Leach *et al.*, 2010). Scenario exercises may represent selected pathways and their underlying narratives.

5.2.2.1 Pathways for transformative change

The concept of pathways has become increasingly popular to analyse how specific sustainability objectives can be achieved. Pathway approaches attempt to manage complexity—in a bounded, exploratory way—and illuminate new ways of achieving specific societal goals (Geels & Schot, 2007; Turnheim *et al.*, 2015). A rich set of literatures on pathways towards sustainability examines how sustainability might be achieved through different trajectories, often addressing the politics of change and seeking profound changes in global socioeconomic structures (Edenhofer & Kowarsch, 2015; Geels & Schot, 2007; Grin *et al.*, 2010; Leach, 2008; Leach *et al.*, 2018; Loorbach *et al.*, 2017; Luederitz *et al.*, 2017; Olsson *et al.*, 2014; Raskin, 2008; Rosenbloom, 2017; Scoones *et al.*, 2015; Sharpe *et al.*, 2016; Swilling & Annecke, 2012). Few analyses straddle the breadth of perspectives considered here (Loorbach *et al.*, 2017; Turnheim *et al.*, 2015).

Pathways are mostly neither deterministic nor linear, but always context-dependent and evolutionary with emergent properties (the future being shaped by the past). Different pathways achieving the same goals will have different socioeconomic and environmental implications (e.g., effects on nature and its contributions to people). These include 'distributional impacts' that raise justice issues in a given system, and in connected systems through telecouplings (i.e., socioeconomic and environmental interactions over distances). Pathways may also be characterised in other ways: speed (time to reach the goals and targets), depth (degree of differences between starting points, current development trajectories and the goals and targets to be achieved), and scope (dimensions that change to achieve the goals and targets) (Turnheim *et al.*, 2015). As one insight that emerges, pathways of fundamental reconfiguration (or system transformation) often go through distinctive phases of destabilisation → disruption → breakdown of internal structures of the old system followed by an emergence and acceleration of novel features (Loorbach *et al.*, 2017).

In this chapter, pathways refer explicitly to trajectories toward the achievement of goals and targets for biodiversity conservation and management of nature and the full array of the SDGs. Because of the transformative change required, our analysis considers the departure from existing development pathways and vested interests/structures, to make space for new and more sustainable pathways

(Loorbach *et al.*, 2017; Sharpe *et al.*, 2016). Part of this departure may occur by deepening and accelerating existing processes of change.

There are several reasons to identify and analyse alternative pathways. First, no method can identify the best feasible pathway *a priori* due to the many uncertainties, complexities, and societal perspectives in coupled human and natural systems. There is a danger of bias in selecting pathways because the "definition of the alternatives is the supreme instrument of power" (Schattschneider, 1960, p. 66). Second, presenting alternative pathways and their uncertainties may allow for constructive public discourse. It is important to think about how pathways are framed as this shapes how they are understood and addressed, structuring the possibilities and privileging certain responses (Rosenbloom, 2017). Third, presenting alternative policy pathways and their trade-offs and consequences may help avoid the misuse of expertise in policy. With several pathways, policymakers cannot legitimize policy pathways by referring to an alleged "inherent necessity" of a certain policy pathway based on an apparent scientific consensus. To avoid severe bias in the assessment, pathways thus ought to reflect several politically important and disputed objectives, ethical values and alternative policy narratives.

5.2.2.2 Scenario studies

This chapter **combines multiple scenario studies** (through an analysis of their key premises, underlying narratives and results) **and other sources to inform our understanding about possible pathways to the SDGs**, as follows:

- **Types of scenarios considered:** Following the typology of the IPBES methodological assessment report on scenarios and models of biodiversity and ecosystem servicse (IPBES, 2016), our main focus in this chapter are **target-seeking scenarios**, also known as normative scenarios. Such scenarios are built by first defining a future target and then how to get from the present to this future, through quantitative and/or qualitative backcasting (Vergragt & Quist, 2011) or scenario-discovery techniques (Gao & Bryan, 2017), for instance. Since there are relatively few target-seeking scenarios, we also included **sustainability-oriented exploratory scenarios** and **policy-screening scenarios**. The sustainability-oriented exploratory scenarios were those scenarios of evolving key drivers, based on sustainability-oriented archetypes or storylines (Hunt *et al.*, 2012; IPBES, 2016; van Vuuren *et al.*, 2012). In policy-screening scenarios (also known as *ex-ante* scenarios), we analysed specific policy options implications in relation to a reference/*status quo* scenario.
- **Spatial scales:** To extract the key elements that constitute the pathways from scenarios, we employed a cross-scale analysis. While global scenarios indicate broad pathway alternatives, scenarios at finer spatial scales provide more detail and insights in the context of local or regional conditions. We therefore enriched our analysis by bringing elements from finer scales to the pathways discussion. Global scenarios alone may not capture the difficulties of implementing certain measures at local to regional scales, or the unwanted consequences of doing so.
- **Nexus-thinking approach:** Given the inherent complexity of analyzing possible achievement of multiple SDGs, we organized our literature search and analysis using a nexus approach to explore complementary and interconnected perspectives related to terrestrial, marine and freshwater social-ecological systems.

5.2.3 Nexus Thinking, Methods of Analysis

5.2.3.1 Nexus thinking to structure the analysis

Achieving goals and targets related to nature and nature's contributions to people requires holistic approaches to integrate multiple disciplines, across space, over time, and among organizational scales. The need for integration in solving complex problems has long been recognized, leading to a variety of approaches and areas of study. In this chapter, we use a systems approach and nexus thinking to identify synergies and trade-offs when discussing pathways for achieving the SDGs—incorporating thinking across scales, domains, sectors and disciplines (Liu *et al.*, 2015b).

The word nexus (derived from the latin "*nectare*", "to bind or tie"), has long been used in multiple fields to refer to approaches that address linkages between multiple distinct entities (Liu *et al.*, 2018). In recent decades, it became increasingly popular as applied to the study of connections among water, energy and food (the WEF or FEW nexus), usually in the context of climate change, and sometimes with the addition of other issues, such as biodiversity protection and human health (Albrecht *et al.*, 2018; Hoff, 2011). We find nexus thinking a valuable approach *to avoid the natural tendency to retreat into intellectual, sectoral, and institutional silos*. This holistic approach is imperative in the context of the SDGs, given that many of the targets are interconnected (Nilsson *et al.*, 2016) and such interactions can be synergistic and/or antagonistic, involving context-dependent trade-offs (Weitz *et al.*, 2018).

For the above reasons, we use nexus thinking to frame the problem of reaching multiple SDGs together. To keep our analysis manageable and understandable in the complex context wherein everything is connected, we structure our analysis around complementary perspectives, in a multilayered approach. Each perspective can be understood as a *focus* (or lens) to view in detail particular links between terrestrial, marine and freshwater social-ecological systems without disregarding linkages to other aspects **(Figure 5.2)**.

The following six foci reflect core challenges related to conserving nature and nature's contributions to people (the mandate of the global assessment) while achieving the SDGs, given both trade-offs and synergies:

1. *Feeding humanity while enhancing the conservation and sustainable use of nature;*
2. *Meeting climate goals without incurring massive land-use change and biodiversity loss;*
3. *Conserving and restoring nature on land while contributing positively to human well-being;*
4. *Maintaining freshwater for nature and humanity;*
5. *Balancing food provision from oceans and coasts with biodiversity protection; and*
6. *Resourcing growing cities while maintaining the ecosystems and biodiversity that underpin them.*

Our analysis respects the "interconnected and indivisible nature" of the 17 goals (UN, 2015). These six foci relate to all SDGs in some way, although they are oriented around some more strongly than others. Some SDGs are easily related to several of these foci (SDG 2 – Zero hunger, for instance), but human well-being, basic needs, human rights and nature protection underlie all the lenses, including attention to their implications for Indigenous Peoples and

THE NEXUS IN THE LANDSCAPE

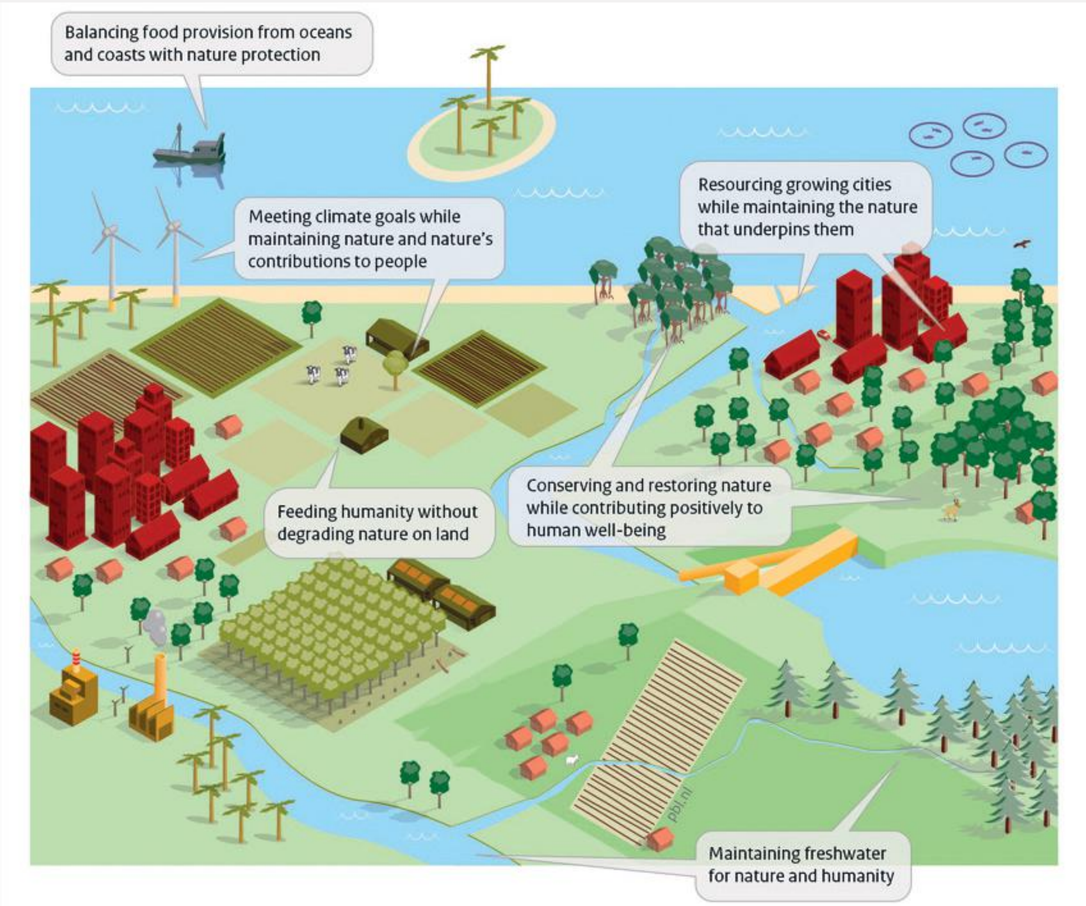

Figure 5 2 **The six interconnected foci of our nexus analysis.**

These complementary perspectives roughly followed divisions in the underlying scenario and pathways literatures addressing a variety of sustainability goals and targets (especially the UN's Sustainable Development Goals, SDGs, and the CBD's Aichi Targets). Source: PBL for this publication.

Local Communities (IPLCs), as **Figure 5.2** illustrates. The first three foci relate strongly to SDG 15 (Life on Land) and its interactions with other SDGs. The fourth addresses freshwater, connecting SDG 6 (Clean Water and Sanitation) to the first three foci through the WEF nexus. The fifth addresses marine resources, also linked to all other foci through the food system, water cycle, pollution and climate change concerns. Finally, the sixth focus addresses cities and their connection to the terrestrial, freshwater and marine resources previously discussed.

We structure our results in Section 5.3 (Pathways derived from the scenario review process) around these foci. For each subsection in 5.3.2, information is organized as follows:

- **Framing the problem**, a brief review about the current situation of the problem under analysis and major trends.
- **What do scenarios say about pathways to achieve the (relevant) SDGs?** We used the available information in the scenario literature (at multiple scales) to identify the *main measures* (actions, policies, governance premises, necessary changes) *directly or indirectly* (through quantified results or narrative premises, for instance) *underlying different scenarios in order to achieve the SDGs simultaneously*. Non-scenario literature was also used to reinforce or complement our synthesis approach.
- **Synthesis about the pathways**, we close each subsection with a synthesis of the main findings, including a diagram illustrating the pathways.

After the six subsections, we conclude 5.3 with a synthesis highlighting common threads across the six foci. We identify levers and leverage points of transformation with a focus on nature and nature's contributions to people (5.3.3). The section emphasizes core convergences and divergences across the different lenses, the synergies and trade-offs between the SDGs, and also the role nature and nature's benefits to people play in reaching the SDGs.

CROSS-SCALE ANALYSIS OF PATHWAYS TO THE SDGS USING NEXUS-THINKING

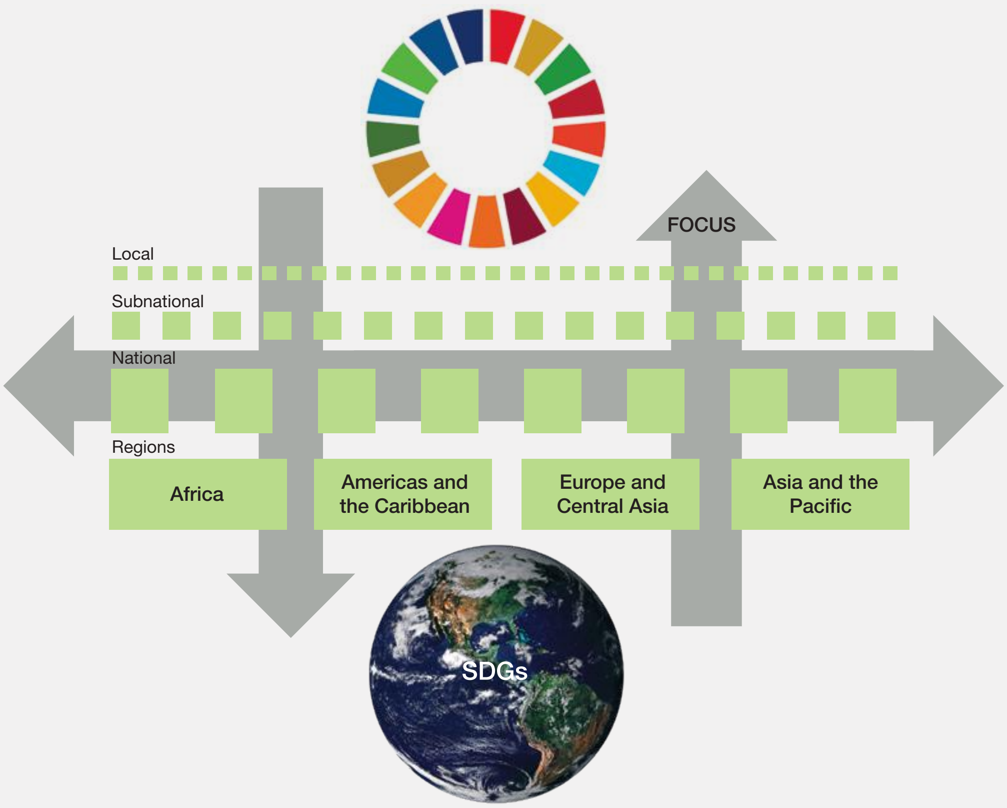

Figure 5 3 **Schematic representation of our multi-scale approach.**

The grey arrows denote the multiple foci we used to structure our analysis. For each focus, we strived to connect information across regions (horizontal arrow) and across spatial scales (vertical arrows).

5.2.3.2 Method for literature search at the global scale

Appendix 5.1 presents the basic search strings we used to select (target-seeking) global scale scenarios. Three alternative strings were used. The first one aimed to encompass all target-seeking scenarios related to nature and nature's contributions to people at the global scale, published after 2006. The second one restricts the search to the selected SDG clusters. The third one expands the selection to some key drivers of change, such as deforestation and restoration processes. To expand the set of studies underlying our analysis, we also investigated global scale exploratory and policy-screening scenario studies, which explicitly followed a sustainability focus in their storylines, with an intent to achieve the SDGs. An example is the new climate scenario SSP1 "sustainable world scenario" of the IPCC (van Vuuren *et al.*, 2017). We recorded key information for each scenario, as the basis for quantitative analysis presented in Section 5.3.1. The literature search for target-seeking scenarios at the global scale yielded 47 studies in total (see Section 5.3.1 and Table SM 5.2 B).

5.2.3.3 Cross-scale analysis

We defined a common process to incorporate information from other scales, to complement global scenarios. The initial source of information about scenarios and pathways at the sub-global scale (regional, national, subnational and local) were the fifth chapters of each of the IPBES regional assessments, which performed broad literature searches on scenarios pertaining their regions. A complementary literature search was conducted for each specific lens/perspective under analysis, similar to the one performed at the global scale. Based on the combined results from all these sources, we tabulated key information about each scenario at different scales (Appendix 5.2). We organized five tables with core information about terrestrial scenario studies (global and the four IPBES regions), and one related to marine scenarios. Each table describes the following: Scale, Region/system, Goal/vision, Type of scenario, Sectors covered, Pathway elements (measures, policies, changes), Scenario 'short name' and Complete reference. We then performed an iterative process to synthesize key information for each scale and region, related to each focus of analysis. Based on this systematization, we distilled key components of pathways projected to achieve the SDGs, which formed the basis for the subsections "What do scenarios say about pathways to achieve the SDGs?", complemented by non-scenario literature and cross-regions linkages. Although we did not adopt a typology of pathways (as in the IPBES European and Central Asia regional assessment), in 5.3 we do indicate alternative—and sometimes contrasting—pathways emerging from the literature. **Figure 5.3** depicts this process.

As mentioned before, this chapter combined methods and procedures to interpret sustainability transitions from different scientific angles. As such, it is an effort towards inter- and transdisciplinary triangulation. Combining the findings from different approaches may enable a more encompassing and more legitimate understanding of the processes, outcomes, and impacts of possible pathways to sustainability. We hope that this will in turn yield more appropriate and legitimate implications for practice and policy (as discussed in 5.4 and chapter 6).

5.3 PATHWAYS DERIVED FROM THE SCENARIOS REVIEW PROCESS

5.3.1 Results of the assessment of global scenarios

5.3.1.1 Overview

The literature search on target-seeking and policy-screening scenarios yielded 47 scenario studies with global coverage. Qualitative, storytelling ("narrative") scenarios were assessed for additional information to determine if, when and why SDGs could be achieved **(Figure 5.4 B)**. At the global scale, target-seeking scenario research is much less elaborated than exploratory scenario research (chapter 4). The IPBES methodological assessment on scenarios and models of biodiversity and ecosystem services notes that target-seeking and policy-screening scenarios have been applied to decision-making mostly at regional and local scales (IPBES, 2016), and therefore are not common at the global scale. Backcasting and scenario-discovery approaches were rare at the global scale, likely due to the inherent complexity of the task at that scale.

The scenarios evaluated consisted of target-seeking scenarios (e.g., Leclère *et al.*, 2018; PBL, 2012; van Vuuren *et al.*, 2015; see **Boxes 5.1 and 5.2**, respectively), followed by policy-screening scenario studies (e.g., Visconti *et al.*, 2016), 'sustainability' exploratory scenarios (e.g., Raskin

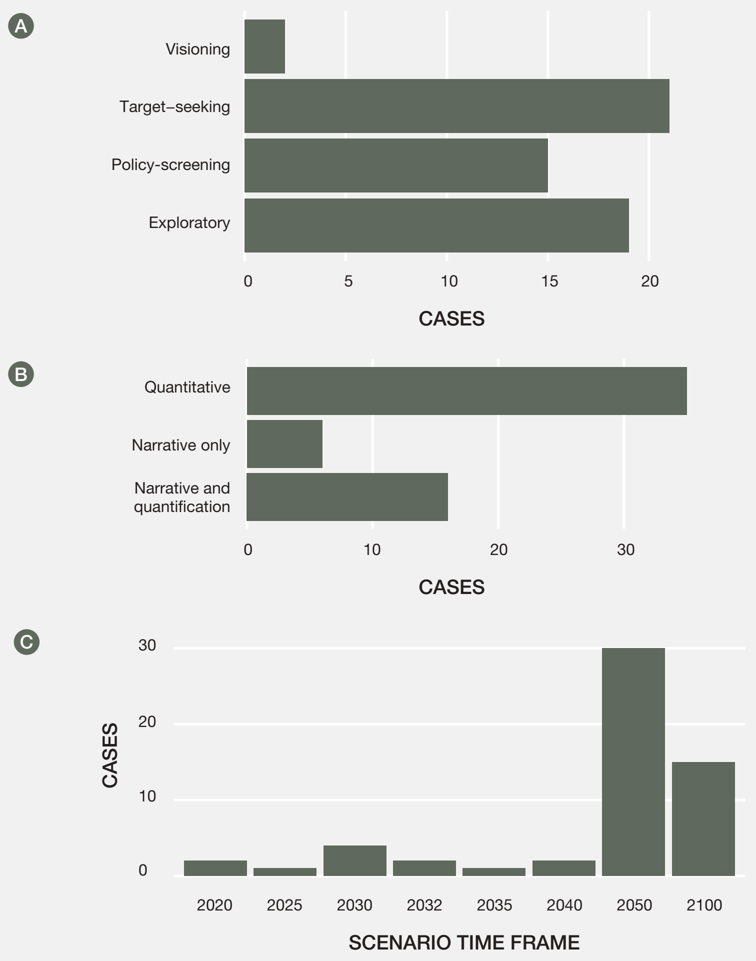

Figure 5 4 **The number of studies from the review on target-seeking scenarios that fulfill the following:**

A target-seeking scenarios, policy-screening scenarios, 'sustainability' scenarios of exploratory exercises, and visioning exercises; B using a quantitative approach, a narrative approach, or both together; and C applying different time frames of analysis (N=34; a given study could score in multiple categories for panel A).

et al., 2002) and a small number of visioning studies (e.g., WBCSD, 2010; see **Figure 5.4 A**). Visioning studies were only taken into account if they went beyond qualitative description of future trajectories for a certain sector and provided quantification and analysis of pathways to realize that vision. The analysis revealed that most selected studies include both narratives (storylines) and quantification of scenarios using models (e.g., UNEP, 2002 Sustainability First Scenario).

In most global scenario studies, biodiversity, ecosystem services (or nature's contributions to people), and implications for human well-being are a few of many aspects being analysed (e.g., PBL, 2012). Regarding temporal scale, long-term projections are most common across the selected studies (present to year 2050, **Figure 5.4 C**). This finding is in line with IPBES (2016), which states that international environmental assessments including scenario exercises typically focus on long timescales. Decision-making, however, often requires both short-term and long-term perspectives (IPBES, 2016), so considering scenarios across different temporal scales is important.

The majority of studies relied on expert knowledge. Only a few incorporated indigenous and local knowledge and perspectives or stakeholder consultations (e.g., Springer & Duchin, 2014). This finding corresponds to IPBES scenarios assessment conclusion that participatory scenario studies predominantly have a local-scale focus, while global scale scenario studies are often developed using expert-based approaches (IPBES, 2016). Participatory scenario methods enhance the relevance and acceptance of scenarios for biodiversity and ecosystem services (IPBES, 2016), and their application could be taken up more often in global-scale scenario exercises.

Sectors most commonly considered

The agricultural sector was the sector most commonly addressed in the scenarios, with 32 of the 47 studies investigating the relationships between agriculture and

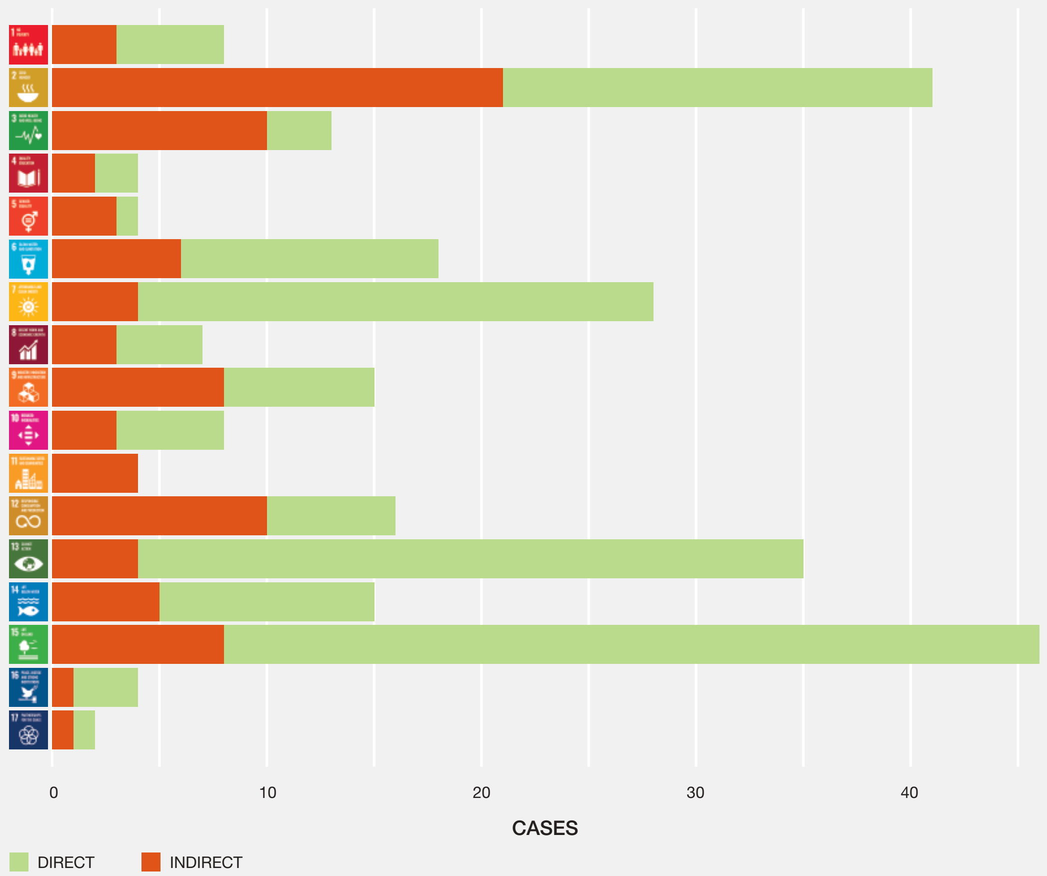

Figure 5 5 **Sustainable Development Goals in Scenarios. Green ("direct") represents scenarios that address an SDG directly; orange represents scenarios that address an SDG only implicitly ("indirect").**

other sectors and factors such as biodiversity, biofuels, deforestation, and climate change (e.g., Eitelberg *et al.*, 2016; Erb *et al.*, 2013; PBL, 2012; Smith *et al.*, 2013; van Vuuren *et al.*, 2015). Concerns ranged from feeding the growing human population to addressing threats from biofuels and managing the availability of land and water (e.g., Flachsbarth *et al.*, 2015; Odegard & van der Voet, 2014; Wirsenius *et al.*, 2010).

The second most prevalent sector was forestry, with 17 studies addressing issues such as land degradation, and competition with agricultural production (e.g., Kraxner *et al.*, 2013; Stavi & Lal, 2015; van Vuuren *et al.*, 2015). In particular, these scenarios addressed issues such as reducing carbon emissions from forest degradation, and competition between forests and biofuel crops (e.g., Smeets *et al.*, 2007; Zarin *et al.*, 2016). Energy and water sectors were considered by 17 and 7 studies respectively. In terms of water, issues addressed include river fragmentation as a threat to river biodiversity, availability of water for agricultural production (particularly emphasizing the threat of agricultural expansion for water resources), and general water efficiency measures needed to reach targets (e.g., Grill *et al.*, 2015; Springer & Duchin, 2014; WBCSD, 2010). The energy sector was addressed largely through efforts to reduce carbon emissions via clean technology, and the competition for land associated with these efforts (Prieler *et al.*, 2013; Rogelj *et al.*, 2018a; van Vuuren *et al.*, 2010, 2017).

SDGs most commonly considered

SDGs pertaining to terrestrial systems were most frequently considered. In particular, SDGs 2 and 15 were commonly investigated, analyzing trade-offs between food security and (terrestrial) biodiversity **(Figure 5.5)**. These studies provide input to investigate the foci on "*Feeding humanity while enhancing the conservation and sustainable use of nature*" Section 5.3.2.1) and "*Conserving and restoring nature on land while contributing positively to human well-being" (*5.3.2.3)*.* Also studied quite frequently were SDGs 6, 7, 12, 13 and 14. The results from the review as well as additional literature thus enables investigating foci related to *Maintaining freshwater for nature and humanity (5.3.2.4)* and *Balancing food provision from oceans and coasts with nature protection (SDG 14, 2, 12; 5.3.2.5)*. Although many studies addressed SDGs 13 and 15, including in concert, additional literature was consulted for the specific lens considering the means of "*Meeting climate goals while maintaining nature and nature's contributions to people***"** (5.3.2.2). Few target-seeking scenarios addressed SDGs 4, 5, 11, 16, and 17. Because of the undisputed relevance of an urbanizing society, however, we investigated the focus "*Resourcing growing cities while maintaining the nature that underpins them*" (5.3.2.6) based largely on secondary literature.

5.3.1.2 Core global studies: integrated pathways to achieve multiple goals

Because detailed examination of particular scenarios and trade-offs is instructive in ways that a general synopsis is not, this section reviews core global studies discussing integrated pathways for achieving multiple goals. Here we pinpoint key characteristics of the pathways discussed in these studies, which feeds into the multi-scale analysis in 5.3.2.

Roads from Rio+20 pathways: this study culminates a series of linked papers and reports (Kok *et al.*, 2018; PBL, 2012, 2014; van Vuuren *et al.*, 2015). It used a backcasting approach to explore the level of effort needed to achieve selected SDGs (accounting for feasibility constraints). **Three alternative pathways were quantified and compared to the 'trend' scenario; each achieved the goals despite variation in management and behaviour change**. The goals align closely with the SDGs (they were based on internationally agreed goals and targets prior to the SDGs) and involve provision of energy and food while mitigating climate change (2 degrees), providing clean air and halting biodiversity loss. The study also examined some related issues including nitrogen, water, and health in the context of population, economic growth, energy and land use. The scenarios were quantified using an integrated assessment model framework IMAGE in combination with related models for biodiversity, human health and climate policy (GLOBIO, GISMO and FAIR, respectively) to provide a global overview while differentiating between world regions (see the IPBES regional assessments for region-specific results). **Box 5.1** synthesizes how the three pathways differ and some key quantitative results in relation to biodiversity.

Alternative pathways to the 1.5 degrees target based on the Shared socioeconomic pathways (SSPs). The SSPs represent five different development trajectories: i.e., sustainable development (SSP1), global fragmentation (SSP3), strong inequality (SSP4), rapid economic growth based on a fossil-fuel intensive energy system (SSP5) and middle of the road developments (SSP2; all are used extensively by the Intergovernmental Panel on Climate Change (IPCC)). Each of the SSPs portrays a storyline quantified using models. These storylines can be combined with different assumptions about climate policy to form a larger context of socioeconomic development and level of climate change (mitigation scenarios, c.f. Riahi *et al.*, 2017; Rogelj *et al.*, 2018b). The sustainable development scenario (SSP1) combined with stringent climate policy is a scenario exploring the route towards a more sustainable world, although the SDGs were not targeted in its development. Mitigation scenarios that achieve the ambitious targets included in the Paris Agreement typically rely on greenhouse gas emission reductions combined with net carbon dioxide removal from the atmosphere, mostly accomplished through

Box 5 1 Roads to Rio+20 Pathways.

Several key **premises** underlie the alternative pathways (Figure Box 5.1.a) and their achievement of sustainability goals (Kok *et al.*, 2018; Table SM 5.3.3):

The **Global Technology pathway** assumes that sustainability objectives are pursued mainly by large-scale application of technological solutions. A high level of international coordination through—for example—trade liberalization and the expansion of global markets drives these responses in all world regions. In terms of land use, sustainable intensification in agriculture may lead to a "land sparing" effect, i.e., efficient use of some lands for production would allow sparing other land from conversion to agriculture and/or dedicate them to conservation (Balmford *et al.*, 2005). The protected area system focuses on continuous natural areas away from existing agricultural land to minimise conflict with agricultural expansion, but large natural areas are not necessarily connected.

The **Decentralized Solution pathway** consists of solutions and technologies that can be implemented on a smaller scale resulting in multi-functional mosaic landscapes and regional diversity, in line with regional priorities. Local and regional markets drive demand. Ecological innovation in mixed land-use systems where natural elements and production landscapes are interwoven may result in a "land sharing" effect (Balmford *et al.*, 2005). Agricultural intensification is achieved by using ecological techniques, such as intercropping, agroforestry, and natural pest control, in combination with natural corridors interwoven with agriculture to enable the extensive use of ecosystem services (Pretty, 2008; Tittonell, 2014). In this pathway, agricultural landscapes comprise at least 30% of natural elements acting as corridors between natural areas, hence reducing fragmentation and providing ecosystem services.

The **Consumption Change pathway** starts from implementing a set of behavioural changes in favour of less resource-intensive consumption. These include ambitious efforts to reduce waste, increase recycling in production chains, reduced energy- and material- intensive lifestyles and a shift towards moderate consumption of meat and dairy, in line with health recommendations. Alongside land "sparing" and "sharing" pathways above, this is the "caring" pathway, reflecting the importance of personal behavioural and consumption choices. This pathway assumes a reduction of 50% in food waste and losses, equalling 15% of the production (IMECHE, 2013). Increases in agricultural productivity are only slightly higher than in the 'trend' scenario. Food consumption change is derived from the Willett diet, characterized by a low meat and egg intake (Stehfest *et al.*, 2009; Willett, 2001).

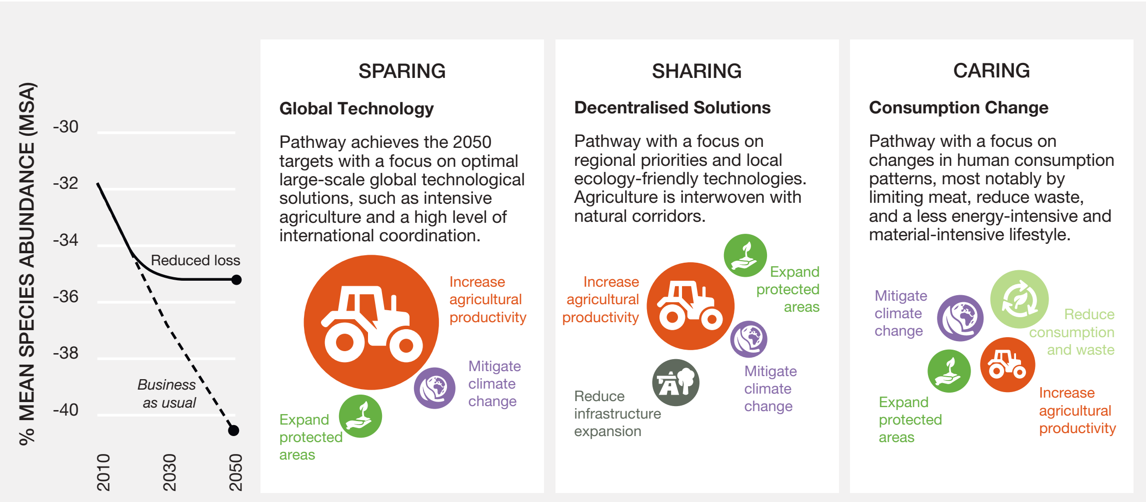

Figure 5 1 A **Schematic representation of three alternative pathways to reduce biodiversity loss represented in the Roads to Rio+20 study (see Table SM 5.3.1/5.3.2 for comparison of premises).**

Source: PBL (2017).

Results

According to the study, all pathways achieve the assumed 2050 targets (Table SM 5.3.1) and would reduce biodiversity loss in the coming decades (avoided Mean Species Abundance (MSA) loss is 4.4-4.8% MSA, compared to 9.5% MSA loss in the 'trend' scenario **(Figure Box 5.1.b)**. Under the Global Technology pathway the most important contribution by far comes from increasing agricultural productivity on highly productive lands. Under the Consumption Change pathway, significant reduction in consumption of meat and eggs as well as reduced waste means that less agricultural production would be required, thus reducing associated biodiversity loss. Under the Decentralised Solutions pathway, a major contribution comes from avoided fragmentation, more ecological farming and reduced infrastructure expansion. Under all scenarios, climate change mitigation, the expansion of protected areas and the recovery of abandoned lands also significantly contribute to reducing biodiversity loss. Further positive results could be achieved by combining various options from the pathways, especially by increased consumption changes in the other pathways. This would result in reversing trends of biodiversity loss (see **Box 5.3** on Bending the curve).

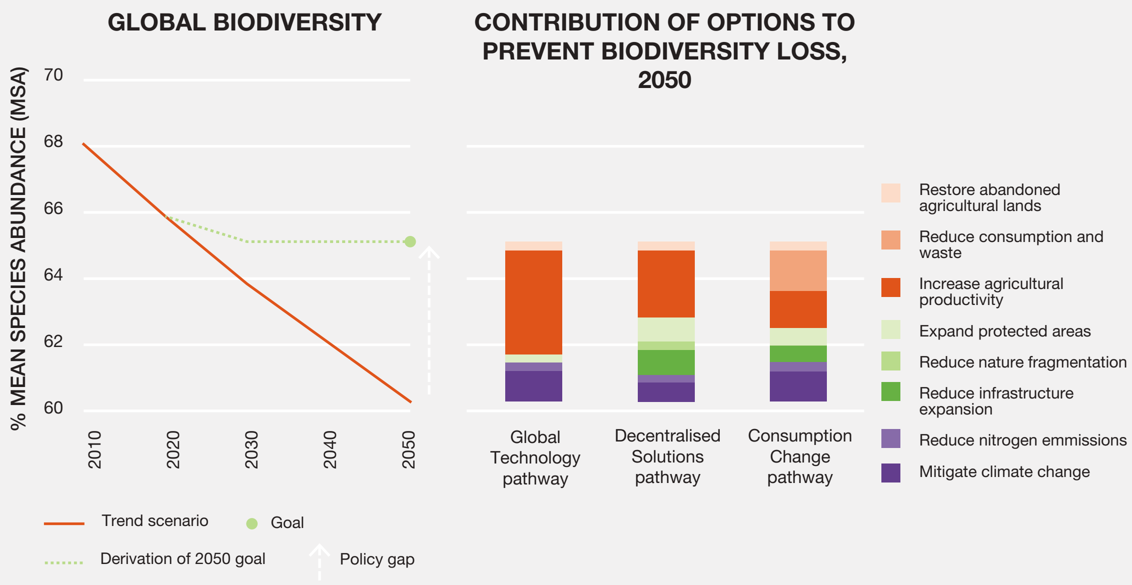

Figure 5 1 B **Measures in the alternative pathways that contribute to biodiversity goals.**

The Rio+20 scenarios have also been used to explore the impact of alternative pathways on extinction risk and abundance of large mammals, revealing that both bottom-up behavioural change (Consumption Change) and top-down technology and policy changes (Global Technology) can reverse global biodiversity decline in the short term, but the onset of delayed climate change impact may require further mitigation strategies.

This study was also one of first to discuss synergies and trade-offs among food, biodiversity, energy, health and climate targets (see Table SM 5.3.3), some of which were explicit in the models. However, some potential trade-offs remain unquantified, such as the use of pesticides and their impacts on health and biodiversity. Source: PBL (2012).

The following publications contain more details (Kok *et al.*, 2018; PBL, 2012, 2014; van Vuuren *et al.*, 2015; Visconti *et al.*, 2016), and there is discussion about their regional results in each IPBES regional assessment.

large-scale application of bioenergy with carbon capture and storage, and afforestation (Doelman *et al.*, 2018; Rogelj *et al.*, 2018a). Using the IMAGE integrated assessment model, van Vuuren *et al.* (2018) explored the impact of **additional measures (beyond SSP mitigation scenarios)** that also include lifestyle change, additional reduction of non-CO_2 greenhouse gases and more rapid electrification of energy demand based on renewable energy (see **Box 5.2** for more detail).

Alternative pathways for bending the biodiversity curve: the 'Bending the Curve' study (Leclère *et al.*, 2018) quantitatively modelled ambitious target-seeking scenarios aiming at reversing biodiversity trends in the 21st century from negative to positive (Mace *et al.*, 2018). This interdisciplinary effort between different modelling communities focuses on biodiversity as affected by human land use and relies on: a) spatially explicit datasets of biodiversity, modelled impacts of land use on biodiversity, and existing scenario frameworks (e.g., SSPs and representative concentration pathways, RCPs); b) integrated assessment models, in particular their spatially explicit land-use modeling components; c) global spatially explicit biodiversity models (also used in chapters 2 and 4) assessing an array of biodiversity impacts from land-use changes. The storylines of existing SSP/RCP scenarios were enriched with more ambitious conservation storylines and quantified via additional datasets generating new scenarios of future trends in land use. These new scenarios considered further actions for biodiversity, such as increased conservation efforts (increased extent and management efficiency of protected areas, increased restoration and landscape-level conservation planning), but

Box 5 2 Alternative pathways to the 1.5 degrees target.

Compared to the default SSP2 1.9 and 2.6 (radiative forcing level of 1.9 and 2.6 W m–2 in 2100, respectively), alternative scenarios to achieve the 1.5 degrees goal are built using the following premises (van Vuuren *et al.*, 2018):

- Rapid application of best available technologies for energy and material efficiency in all relevant sectors in all regions;
- Higher electrification rates in all end-use sectors, in combination with optimistic assumptions about integration of variable renewables and costs of transmission, distribution and storage;
- High agricultural yields and application of intensified animal husbandry globally;
- Implementation of best available technologies for reducing non-CO_2 emissions and full adoption of cultured meat in 2050;
- Consumers change their habits towards a lifestyle that leads to lower GHG emissions (less meat-intensive diet, less CO_2-intensive transport, less intensive use of heating and cooling and reduced use of several domestic appliances);
- Lower population growth (compatible with SSP1);
- The combination of all options described above.

Results

Although the alternative options explored greatly reduce the need to actively remove atmospheric CO_2 to achieve the 1.5 °C goal, nearly all scenarios still rely on bioenergy with carbon capture and storage and/or reforestation (even the hypothetical combination of all alternative options still captured 400 $GtCO_2$ via reforestation). Although not directly estimating impacts on biodiversity targets, these results are important due to the large-scale reforestation process envisioned in the mitigation scenarios. The set of alternative scenarios suggests a diversity of possible transition pathways, including via changing consumption patterns.

The results point out the need for a more diverse portfolio of options than currently discussed in the mitigation scenarios and an open debate concerning their contributions. This could provide more flexibility to ensure that goals are reached. However, it is important to note that the adoption of alternative pathways also might convey substantial regional impacts. To illustrate, **Figure Box 5.2** compares the spatially explicit results of SSP1 and SSP1 1.9, as implemented by the IMAGE model in Doelman *et al.* (2018).

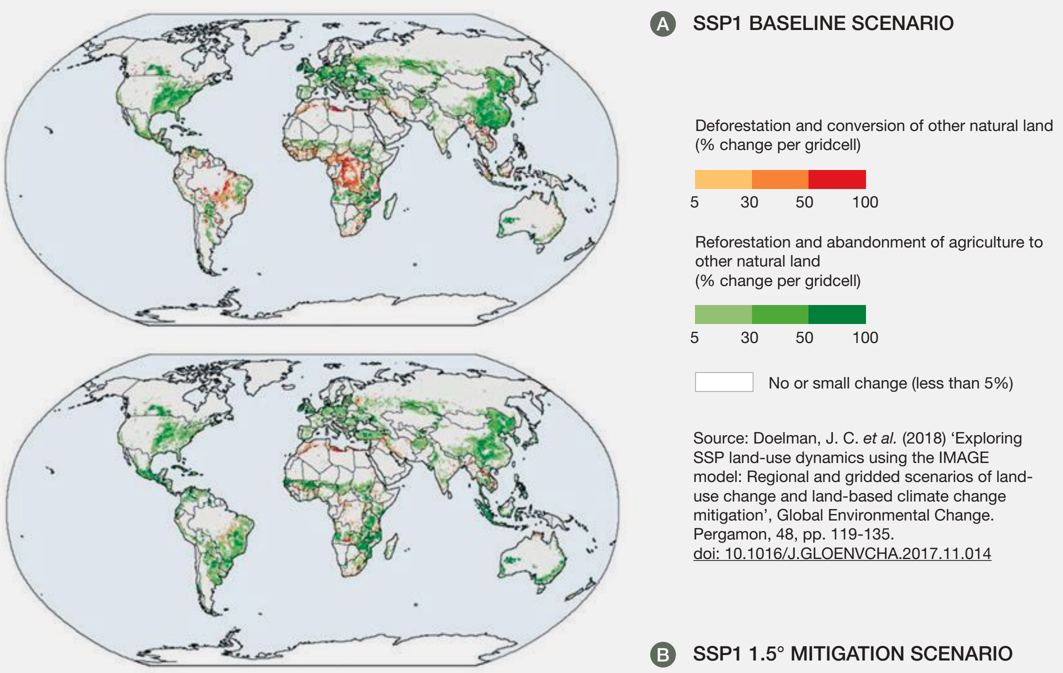

Figure 5 2 **Change in land use (percentages of grid cells) between 2010 and 2100; deforestation and conversion of other natural land to agriculture (red) and reforestation and abandonment of agriculture to other natural land (green) for SSP1 baseline scenario and SSP1 1.5 °C mitigation scenarios (1.9 W/m²).**

Source: PBL for this publication.

Box 5 3 Bending the curve scenarios: towards pathways for ambitious biodiversity targets.

In addition to a baseline (BASE) scenario (based on the "Middle of the Road" SSP2), this study considers six "wedges scenarios" in which various efforts are implemented in order to "bend" the curve of biodiversity loss. The scenarios do not assume strong climate mitigation efforts, nor do they account for future changes in climate or any threat to biodiversity other than habitat loss. The **premises** underlying the six wedge scenarios are as follows:

Increased conservation efforts ("C scenarios"):

a) Increasing protection: any change in land use detrimental to biodiversity (according to PREDICTS' Biodiversity Intactness Index (Hudson *et al.,* 2017)) is ceased from 2020 onwards for all areas identified by the potential protected areas layer (see sections 4.1 and 5.2 in Leclère *et al.*, 2018).

b) Increasing restoration and landscape-level conservation planning: over the entire land area, incentives are gradually put in place to favor land-use changes resulting in biodiversity improvements from 2020 onwards. The net impact on biodiversity (gain or loss) of a particular land-use change is based on PREDICTS' Biodiversity Intactness Index for the two land uses, while the relative importance (for biodiversity) of a given parcel of land derives from the regional restoration priority layer (see sections 4.3 and 5.2 in Leclère *et al.*, 2018).

Demand-side efforts beyond SSP1 ("DS scenarios"):

a) Shifting towards healthier diets: dietary preferences evolve towards 50% less meat compared to the baseline scenario, linearly between 2020 and 2050 (the corresponding animal calories are replaced by plant-based calories) except for regions with low shares of meat in diets like Middle-East, Sub-Saharan Africa, India, Southeast Asia and other Pacific islands (where dietary preferences follow the reference scenarios)..

b) Reducing waste throughout the food supply chain: total waste (losses in harvest, processing, distribution and final household consumption) decreases by 50% by 2050 compared to the baseline, linearly between 2020 and 2050.

Supply-side efforts ("SS scenarios"):

a) Sustainably increasing productivity: crop yields develop following SSP1, assuming in particular a rapid convergence of land productivity in developing countries to that of developed countries.

b) Increasing trade in the agricultural sector: trade of agricultural goods develops according to SSP1, with a more globalized economy and reduced trade barriers.

Combined efforts scenarios: the above efforts are combined by pairing increased conservation and supply-side efforts in the C+DS scenario, increased conservation and supply-side efforts in the C+SS scenario, and all efforts together in the integrated action portfolio (IAP) scenario.

Results show that bending the curve is possible within the 21[st] century for several feasible driver scenarios. **Figure Box 5.3** shows that combining different action wedges allow biodiversity trends to be reversed before 2050 (IAP scenario), instead of continuing declines for BASE scenario. This predicted reversal of trends is similar across all metrics, indicating that future land-use scenarios can be robustly favorable to biodiversity.

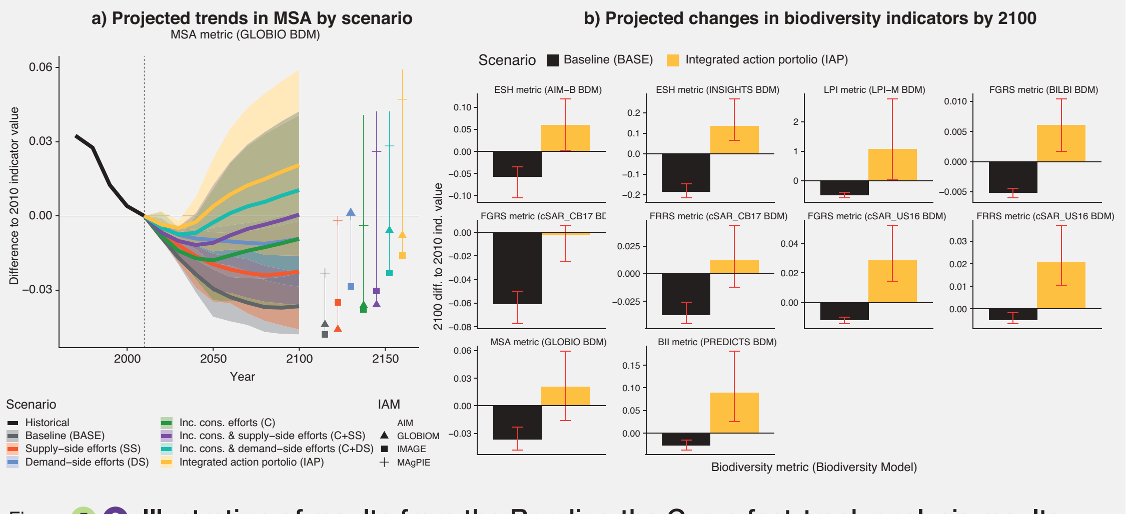

Figure 5 3 **Illustration of results from the Bending the Curve fast-track analysis results.**

The left panel illustrates the estimated change in GLOBIO's Mean Species Abundance index (MSA) from 2010 to 2100 (as compared to 2010) for the land-use component of four integrated assessment models (AIM, GLOBIOM, IMAGE and MAgPIE; the range across IAMs is depicted by ribbons, the average by lines) and 7 scenarios between a business as usual

(BASE) and an Integrated Action Portfolio (IAP) scenario cumulating all efforts to reverse biodiversity trends. The right panel presents the change in various biodiversity indicators estimated by 2100 as compared to 2010 for 2 scenarios (BASE and IAP): BILBI and countryside Species Area Relationship models provide measures of extinctions (the Fraction of Regionally/Globally Remaining Species FRRS & FGRS); GLOBIO and PREDICTS both provide measures of ecosystem integrity through the Mean Species Abundance (MSA) index and the Biodiversity Intactness Index, (BII) respectively; INSIGHTS and AIM-Biodiversity provide a measure of habitat changes through the Extent of Suitable Habitat (ESH) index; and wildlife population density trends are estimated through the Living Planet Index (LPI). The bars indicate the average across IAMs, while red error bars indicate the dispersion across IAMs.

The multi-model assessment framework allows for quantitative assessment of uncertainties associated with land-use projections and their underlying drivers. The contribution of individual drivers and combinations of drivers to stepwise biodiversity improvements has also been quantified. For example, although larger conservation and restoration efforts are key to halting loss and engaging biodiversity onto a recovery path, such a reversing of global biodiversity trends will only be possible by 2050 if our food system achieves a feasible but ambitious transformation.

also demand-side (shift in diets towards less meat, reduced waste) and supply-side efforts (crop yield improvement and reduced trade barriers). Scenarios were fed into the integrated assessment models to generate land-use change projections. Finally, biodiversity models were used to assess whether these spatially explicit land-use change projections over the 21st Century are able to reverse biodiversity trends on a multitude of biodiversity indicators. **Box 5.3** describes measures embedded in the pathways and synthesizes core results.

Two core conclusions can be drawn from the analysis of these studies:

1. **Pathways and narratives:** Different pathways can potentially yield achievement of the same sustainability goals, sometimes with contrasting narratives.**Recognizing the existence of alternative narratives, including their complementarities and tensions, is central to advance the discussion of necessary transformations**, as alternative pathways pose different challenges, trade-offs and synergies among targets (Leach *et al.*, 2010; Luederitz *et al.*, 2017; **Boxes 5.1-3**). For instance, focusing on lifestyle change may greatly decrease the need for future choices related to resource use. Different narratives also uncover power structures and winners and losers of anticipated transformations. Reduced meat production may have implications for economies of producing countries. System lock-ins may be reinforced by certain pathways. Relying only on land-sparing pathways may have positive implications for large-scale industrial agriculture while undermining small-scale farmers. In the following sections, alternative narratives and pathwaysare recognized and highlighted through examples.

2. **SDGs and the Paris Agreement goals:** Scenarios consistent with the Paris goals to reduce GHG emissions include options such as switching to zero- and low-carbon energy options, increasing energy efficiency, using carbon capture and storage (CCS), reducing non-CO_2 GHG emissions, eliminating emissions related to land-use change and stimulating afforestation. Van Vuuren *et al.* (2018), for instance, concluded that GHG targets can be achieved through reduced production of meat and dairy products and intensification of agricultural production, together limiting conversion of unmanaged land. Such a pathway may also promote land-use changes that minimize releases of carbon stored in vegetation and soils, thereby potentially preserving some biodiversity-rich areas. However, mitigation scenarios may also rely on development of short-rotation bioenergy plantations—increasing pressure to convert unmanaged land—and afforestation of non-forested areas for both carbon sequestration and extractive use.

These climate mitigation scenarios suggest four key points: (a) the **biodiversity impacts of afforestation** will depend on where afforestation occurs and how the resulting plantations and forests are managed; (b) such pathways indicate a **land-constrained scenario for food production** due to competition with large-scale reforestation and biofuels; (c) a key underlying premise of the SSPs pertains to population size and ensuing consumption trends. The population dynamics for the different SSPs (Abel *et al.*, 2016) range from a very high global population of almost 13 billion by 2100 down to just 7 billion in SSP1—a shade lower than the current population of 7.6 billion. Therefore, **the feasibility of the options discussed above depends on reduced population growth, and consequently a considerably lighter pressure on resources** (energy, land, water)(see 5.4.1.2). Finally, (d) **such studies assume appropriate, timely and effective governance of such large-scale transformations** in different geographic contexts (see 5.4.2.1-5).

5.3.2 How to achieve multiple SDGs: a cross-scale analysis using nexus thinking

5.3.2.1 Feeding humanity while enhancing the conservation and sustainable use of nature

Framing the problem

Today, agriculture accounts for 38% of Earth's terrestrial surface (Foley *et al.*, 2011) and produces enough calories for all people in the world (Ramankutty *et al.*, 2018). Many millions of people have been lifted out of hunger but food security continues to be a major challenge globally (Godfray *et al.*, 2010). The Food and Agriculture Organization (FAO) reports that the number of undernourished people increased to 821 million in 2017. Similarly, stunting and wasting continue to affect children under the age of five, with more than 150 million and 50 million children affected in the same year, respectively. At the same time, obesity is rising, affecting more than 670 million people worldwide (FAO, 2017).

There are many reasons for the mismatch between the increased availability of food and the continued existence of undernourishment. On the supply side, food production is not evenly distributed globally, and regions differ in terms of yield, irrigation, nutrient application and climate impacts, among other factors (Lobell *et al.*, 2011; Monfreda *et al.*, 2008; Mueller *et al.*, 2012; Ramankutty *et al.*, 2018; Searchinger *et al.*, 2013). Consumption is further impeded in some places by access, affordability, and poverty. Added to this is increasing food waste across the food value chain from production to consumption (Gustavsson *et al.*, 2011; Odegard & van der Voet, 2014; Smith *et al.*, 2013), market influences on food price (Headey & Fan, 2008; O'Hara & Stagl, 2001) and other factors affecting the distribution of food. Besides, in many regions the expansion of industrial agriculture–via incentives from trade agreements, government subsidies, and global mergers of large agribusinesses corporations–threatens small-scale agriculture, still a significant and in many countries the main contributor to food production and food security (IPES-Food, 2016). Beyond agriculture, hunting, gathering, and herding systems continue to be crucial for locally appropriate food security, and such systems have sometimes suffered at the expense of subsidies for and externally imposed notions of appropriate nutrition and food production (Council of Canadian Academies, 2014; EALLU, 2017). Despite their importance, these non-agriculture food systems represent an important gap in literatures on scenarios and pathways (except for fishing, see 5.3.2.5 and also 5.3.2.4); accordingly, our focus in this section is largely on agriculture.

Agriculture is a fundamental driver of global biodiversity loss through its area expansion and the increase of pollutants and of resources used in production (including irrigation water, fertilizers and pesticides) (see chapters 2, 3). Meanwhile, agriculture depends strongly on healthy ecosystems for a diversity of supporting ecosystem processes, including nutrient remineralization, soil health, insect pollination, and biological pest control (Power, 2010; Seppelt *et al.*, 2017). **The core question addressed here is whether and how agriculture and associated food systems will be able to meet the needs of the global population in the coming decades, without further degrading natural resources (and possibly even restoring some).** Addressing this question requires consideration of the globalization of food systems and the varying contributions and roles that different regions play in food production **(Figure 5.6)**.

We organize the discussion about pathways in relation to agricultural production, the supply chain and consumers. While much of the literature has focused on reconciling agricultural production and conservation, other issues also need attention. These include food distribution systems, waste, poverty, inequality and personal food preferences, all of which provide direction for tackling hunger and malnutrition, and ultimately, environmental degradation (Bennett, 2017; Cassidy *et al.*, 2013; Tilman & Clark, 2014). It is also critical to reflect on current trends of global food production systems becoming more capital-intensive. The concentration of food production in fewer hands, and the centralized control of inputs pose a significant threat to small-scale agriculture (FAO, 2017).

What do scenarios say about how to achieve these goals?

Agricultural production pathways

Considerable debate addresses how best to balance food production and nature conservation, minimizing land clearing and biodiversity loss (Balmford *et al.*, 2005; Bruinsma, 2011; Erb *et al.*, 2016; Foley *et al.*, 2011; Kok *et al.*, 2014; Phalan *et al.*, 2011; Smith, 2018; Smith *et al.*, 2013; Tscharntke *et al.*, 2012). Two interconnected aspects are key: (1) where food is produced and nature is conserved (spatial distribution of nature and agricultural lands), and (2) how and by whom food is produced.

Some argue that achieving this balance requires land sparing (intensification of agriculture for high yields and the setting aside areas for conservation—a binary approach), while others argue for land sharing (integrated approaches where these two forms of land-use are blended and wildlife-friendly techniques are applied). Based on different approaches, scholars independently come to the conclusion that agricultural yields can be increased substantially without further expansion of agricultural area (Delzeit *et al.*, 2018; Erb *et al.*, 2016; Mauser *et al.*, 2015) but with intensification of land use. In the extreme, biologist E. O. Wilson has called for protecting "half Earth" (Wilson, 2016), producing more and healthier food through sustainable intensification on existing farmland, and returning the other half of land to nature. Lately, many authors have argued that this simplified dichotomy ("land sparing" vs. "land sharing") limits future possibilities (Kremen, 2015). A stringent application of one of the two strategies everywhere is undesirable, as what is optimal may strongly differ regionally based on socioeconomic, cultural and ecological characteristics—and the region's role in global food systems **(Figure 5.6)**.

This leads to another important debate regarding the nature and scale of agricultural systems. Agro-industrial systems, consisting of input-intensive monocultures and industrial-scale feedlots currently dominate farming landscapes (FAO, 2017; IPES-Food, 2016). The uniformity at the heart of these systems, and their reliance on chemical fertilizers, pesticides and preventive use of antibiotics, systematically yields negative outcomes and vulnerabilities, which might lead to system lock-ins (Geiger *et al.*, 2010; Hunke *et al.*, 2015; Wagner *et al.*, 2016). To avoid such problems, there is a need to scale up sustainable practices, including agroecology (FAO, 2017; IPES-Food, 2016; Muller *et al.*, 2017; Rockström *et al.*, 2017). A recent study explored the role that organic agriculture could play in sustainable food systems (Muller *et al.*, 2017). These authors showed that—in combination with reductions of food waste and food-competing feed, with correspondingly reduced production and consumption of animal products—organic agriculture could feed the world using less land than the reference scenario, and that it could also bring several environmental benefits, including a decrease in pesticide use.

Agroecology practices can play a key role. Applied to small-holders they can boost food security; smallholders rather than large-scale farming are the backbone of global food security efforts, given that 80% of the hungry live in developing countries and 50% are smallholders (Tscharntke *et al.*, 2012). The move towards sustainable agriculture may include the adaptation and transfer of agroecological practices and technologies to areas and nations with relatively low yields ('bridging the yield gap'; Pradhan *et al.*, 2015). Such efforts could enable more efficient nutrient use worldwide, but they are no substitutes for regional strategies to achieve food security. Payment for ecosystem services (PES) programs are frequently mentioned in regional to local scenarios (SM 5.2) as an important complementary measure to help facilitate the transition (e.g., Kisaka & Obi, 2015; see 5.4.2.1 about incentives).

The majority of current integrated global scenarios largely rely on a land sparing/intensification approach (see Section 5.3.1.2, SM 5.2.B), allocating food production across the globe to the most suitable lands, and envisioning extensive land restoration. The Roads to Rio+20 is an exception, also representing a land sparing pathway **(Box 5.1)**. Regional to local scenarios (SM 5.2.C to F) tend to explore multiple pathways, detailing the challenges and opportunities of such pathways, and in some cases contrasting perspectives. Regional to local scenarios highlight the following as core pathway elements to achieve the goals of food production and nature conservation: spatial planning; strengthened protected areas; measures to avoid the social and environment rebounds of agricultural intensification; resolution of land tenure issues; routine law enforcement; participation in strengthened governance structures. The importance of international cooperation and cross-national governance structures has been stressed by several scenario studies given the globalization of production and the need to upscale local innovations (Geels *et al.*, 2016; PBL, 2014; Pouzols *et al.*, 2014; van Vuuren *et al.*, 2015).

Consumer pathways: changes and diets and pressure for certified products

Consumers can influence supply chains and agriculture production through consumption choices, including changes towards healthier and environmentally friendly diets. The heterogeneous trends of population growth and urbanization across different regions, and different countries' positions as consumers or producers in the globalized food system, underlie such discussions.

At the global scale (Table SM 5.2 B), several authors have discussed the impacts of alternative diets on land-cover change and, consequently, on biodiversity loss (Delzeit *et al.*, 2018; Erb *et al.*, 2016; Popp *et al.*, 2010; Schader *et al.*, 2015; Stehfest *et al.*, 2009). For instance, Stehfest *et al.*'s (2009) four scenarios of dietary variants—all of which reduce meat consumption (ranging from partial to complete elimination of meat from global diets)—lessened projected land-use change (and impacts on ecosystem services more broadly) and emissions. Potential instruments discussed in such studies include regulation, economic incentives, and information campaigns.

Regional to local scenarios focused less on consumption and diet changes, except in the US and EU. In the **United States**, for instance, Peters *et al.* (2016) evaluated ten alternative diet scenarios (varying the content of meat and dairy consumption) based on projected human carrying capacity (persons fed by unit land area). Their results indicate that: (a) diet composition greatly influences overall land footprint, and imply very different allocation of land by crop type; (b) shifts toward plant-based diets may need to be accompanied by changes in agronomic and horticultural research, extension, farm operator knowledge, infrastructure, livestock management, farm and food policy, and international trade; and (c) diets with low to modest amounts of meat outperform a vegan diet, and vegetarian diets including dairy products performed best overall.

In meat producing countries like **Brazil**, recent scenario studies tend to focus on measures to transform cattle ranching (see for example MCTI, 2017; Strassburg *et al.*, 2014; see Table SM 5.2.C). These studies argued that even with current trends in meat consumption, a boost in the current low productivity of the sector—combined with adequate measures to avoid social and environmental rebounds of intensification—could decrease deforestation and even liberate area for restoration. In contrast, global scenarios, particularly recent ones aligned to 1.5°C targets (see **Box 5.2 and 5.3**), tend to consider a reduction in meat consumption as a necessary measure, given competition for land (biofuels and reforestation), emission and pollution concerns.

Finally, consumer pressure for goods produced in an environmentally friendly and socially just manner is a strong mechanism for transforming food systems. Certification programs are often mentioned as an important pathway element in scenarios at all scales (SM 5.2), as further discussed below (and in 5.4.3.2; chapter 6).

Supply chain pathways

Supply chains link producers and consumers via local to global networks of processors, traders, retailers, investors and banks. The relatively small number of actors (compared to producers and consumers) provides opportunities for levers of transformation, as such key actors may influence decisions made by primary producers and others throughout supply chains (Kok *et al.*, 2014). Partnerships between public and private actors involved in supply chains seem promising for mainstreaming biodiversity protection and engaging multiple levers of change.

A good example of supply chain initiatives is the Soy Moratorium in Brazil's Amazon, a production system telecoupled via global markets (see also chapter 6). This Moratorium was the first voluntary zero-deforestation agreement implemented in the tropics and set the stage for supply-chain governance of other commodities, such as beef and palm oil (Gibbs *et al.*, 2015). In response to pressure from retailers and nongovernmental organizations (NGOs), major soybean traders signed the moratorium, agreeing not to purchase soy grown on lands deforested after July 2006 in the Brazilian Amazon. A monitoring system verifies individual producers. Although few integrated quantitative scenarios represented such measures explicitly, qualitative scenarios often mentioned them as key elements, tied to other governmental and civil society measures (for instance, Aguiar *et al.*, 2016).

The trend of concentration of food systems in few companies also tends to create major asymmetries in economic and power relations. Such asymmetries must also be addressed to ensure fairness and underpin necessary changes regarding food waste, distribution, and more sustainable and healthier practices (IPES-Food, 2016). One core example is the vested interests of large companies that produce pesticides and chemical inputs.

5.3.2.2 Meeting climate goals while maintaining nature and nature's contributions to people

Framing the Problem

Under a business-as-usual scenario, global demand for land is projected to increase substantially. An expansion of agricultural land and bioenergy plantations may leave little room for preserving natural habitats and biodiversity (Secretariat of the Convention on Biological Diversity, 2014). Many more stringent climate mitigation scenarios (reaching 450 ppm but also 550 ppm CO_2eq concentrations by 2100) rely on large-scale deployment of bioenergy with carbon capture and storage (BECCS) (Rogelj *et al.*, 2018b; Smith *et al.*, 2014). The bioenergy crop area required by 2100 is estimated at 150 to 600 Mha (Rogelj *et al.*, 2018a). Potential implications for biodiversity have been explored (Meller *et al.*, 2015), but only a few global bioenergy scenario studies explicitly addressed biodiversity targets and SDGs (e.g., Beringer *et al.*, 2011; Erb *et al.*, 2012; Heck *et al.*, 2018; Leclère *et al.*, 2018; see also 5.3.1.2). It has also been suggested that freshwater biodiversity is severely threatened by ongoing and future development of hydropower (Hermoso, 2017), but we are not aware of any global hydropower scenarios that explicitly address impacts on biodiversity and ecosystem services.

Global energy production from various bioenergy systems in 2018 generates about 50 EJ per year. In some regions, bioenergy production generates substantial economic benefits for states and increases employment and individual incomes (Smith *et al.*, 2014). Bioenergy production in scenarios reaching the 1.5° C target range from 40 to 310 EJ per year (Rogelj *et al.*, 2018b). Major bioenergy systems include industrial organic residues, forest and agricultural residues, dedicated biomass plantations and optimal forest harvesting. Dedicated biomass plantations include annuals (e.g., corn and oil crops), perennials (e.g., sugarcane, oil palm and perennial grasses) and wood-based systems such as short rotation woody crops (see Creutzig *et al.*, 2015; Smith *et al.*, 2014 for a more detailed classification.

Substantial climate mitigation potentials could also be generated by reducing demand for traditional biomass, which until recently accounted for ~80% of current bioenergy use and helps meet the cooking needs of

~2.6 billion people (Chum *et al.*, 2011; IEA, 2012). Ecosystem-based non-bioenergy climate mitigation also has substantial potential without adverse effects on biodiversity and food security. So-called 'natural climate solutions' include a wide range of measures, such as reforestation and changes in forest management, fire management, changes in fertilizer use in grasslands as well as coastal and peat restoration (Griscom *et al.*, 2017). But all such solutions have adverse effects, so scenarios are key for considering trade-offs in context.

Land-based climate mitigation scenarios achieving multiple sustainability goals

Global bioenergy potentials and scenarios are commonly generated with Integrated Assessment Models (IAMs), which explicitly account for competing land demands (Rogelj *et al.*, 2018b), and are consistent with estimates from other global biophysical modelling approaches (Beringer *et al.*, 2011; Erb *et al.*, 2012; Heck *et al.*, 2018; Kok *et al.*, 2018; Meller *et al.*, 2015). BECCS from dedicated plantations in accordance with SSP2 and RCP2.6 would most likely lead to a further transgression of planetary boundaries for land-system change, biosphere integrity and biodiversity, and biogeochemical flows (Heck *et al.*, 2018). So-called second- and third-generation bioenergy systems (IEA & FAO, 2017), such as the use of agricultural residues, and biofuels produced from lignocellulosic ethanol and algae, often have a lower impact on biodiversity and the environment in general. An interpretation of the SSPs with five IAMs with distinctive land use models suggests substantial potential for climate mitigation through improved agricultural management and second-generation bioenergy crops in combination with BECCS, while preserving or even enhancing the extent of natural ecosystems and carbon stocks, in particular in an SSP1 world (Popp *et al.*, 2017).

However, in current models for large-scale scenarios, biodiversity targets have only been included in rather simplistic ways, such as an additional constraint for land allocation, e.g., excluding protected areas from bioenergy or food production (Beringer *et al.*, 2011; Erb *et al.*, 2012; Meller *et al.*, 2015). The global pathways (SSPs) and associated models still lack many processes important to quantify changes in habitat quality and biodiversity (Harfoot *et al.*, 2014; Meller *et al.*, 2015), particularly at local scales (Kok *et al.*, 2017), implying high uncertainty in future impacts of large-scale deployment of bioenergy systems on biodiversity and ecosystem services (Meller *et al.*, 2015).

Griscom *et al.* (2017) estimated that 'natural climate solutions' can provide 37% of the climate mitigation needed until 2030 for a better-than 66% chance of reaching the 2 degrees Celsius target, without adverse effects on biodiversity and food security, and with likely co-benefits for biodiversity. Carbon storage, climate mitigation effectiveness and biodiversity can, for example, be promoted if trees are allowed to grow older in certain temperate forests (e.g., Law *et al.*, 2018). Results from a global analysis, however, suggest that optimal forest harvest ages in terms of climate mitigation efficiency (including life-cycle analyses) often deviate from those ages that promote biodiversity the most (Oliver *et al.*, 2014) and high biodiversity is often found in low-biomass systems (Bond, 2016; Myers *et al.*, 2000). Abreu *et al.* (2017), for example, found strong negative effects of fire suppression on plant and ant richness in the savannahs of the Brazilian Cerrado, a global biodiversity hotspot, where carbon storage was increased by fire suppression. Nevertheless, a recent study with a global integrated energy-economy-land-use modelling system including a wide range of climate mitigation activities suggested that it is feasible to reach the 2 degree Celsius and even the 1.5 degree Celsius target of the Paris Agreement, with co-benefits for air quality, food and energy prices, and without substantial negative effects on biodiversity (Bertram *et al.*, 2018). These outcomes were achieved via a reduction of agricultural trade barriers, no further increases in first-generation biofuels, an increase in the protected forest area and an increase in carbon pricing (Bertram *et al.*, 2018). 'Bending the curve' scenarios also suggest substantial potential for improved land management and synergies between climate mitigation and biodiversity, but also trade-offs (see section 5.3.1.2, **Box 5.3** and Kok *et al.*, 2018).

Synthesis and open questions about climate mitigation pathways

Different bioenergy systems can have very different impacts on biodiversity and ecosystem services (Meller *et al.*, 2015). Intensively managed bioenergy monocultures, such as sugarcane, maize/corn, soybeans, and oil palm have roughly similar negative impacts as other forms of intensive agriculture on biodiversity and ecosystem services more broadly, which raises concerns about their future deployment. The global potential of second- or third-generation bioenergy systems is more uncertain than the above first-generation systems. Alternatively, establishing bioenergy systems that integrate multiple functions can also promote biodiversity (Creutzig *et al.*, 2015; Meller *et al.*, 2015). For example, when combined with agroforestry or installed on degraded land, oil palm plantations can generate co-benefits on food production, carbon storage and biodiversity (Creutzig *et al.*, 2015; Smith *et al.*, 2014). It has also been suggested that marginal and degraded lands, currently not used for food production, might have a substantial potential for bioenergy production. However, how much land is available or unused has been debated (Creutzig *et al.*, 2015), and many areas considered marginal in terms of their agricultural or forestry potential harbour rich biodiversity (Bond, 2016; Myers *et al.*, 2000). Also, 'low-input high-diversity' (LIHD) mixtures of native grassland perennials, for example, can have higher energy yields than monocultures, increase carbon storage in soils, benefit biodiversity and ecosystem services, and they can be grown on agriculturally degraded soils (e.g., Tilman *et al.*, 2006b). Even for the European Natura2000 protected area network, a large potential of low-input high-diversity bioenergy production has been suggested (Van Meerbeek *et al.*, 2016). However, intensively managed monocultures often have higher yields and are, therefore, favored by current price and policy incentives, even though they perform poorly when considering multiple ecosystem services (e.g., Werling *et al.*, 2014). Forest residue use also has large potential, but it can also decrease old-growth forest structures, such as deadwood, which are important habitats for many species (Meller *et al.*, 2015).

Large-scale deployment of intensively managed first-generation monoculture bioenergy crops would have profound negative impacts on biodiversity and many ecosystem services but a comprehensive quantification of such effects at the global scale is missing. A recent study concluded that a low-emission scenario with BECCS might affect global vertebrate diversity as negatively as a high-emission scenario with stronger climate change but without BECCS (Hof *et al.*, 2018). Nevertheless, substantial additional potential for bioenergy exists without compromising biodiversity and ecosystem services, but the implications of different bioenergy systems for a variety of ecosystem services and sustainable development are often poorly captured in scenario studies.

Other ecosystem-based climate mitigation activities surely also have large potential for sequestering carbon cheaply while providing multiple ecosystem services, and boosting biodiversity (Griscom *et al.*, 2017). It is, however, difficult to generalize under which conditions certain management actions preserve biodiversity and achieve an optimal supply of several ecosystem services. Optimal approaches (balancing trade-offs of production and conservation) are region- and ecosystem-specific and include considerations of both biological and livelihood diversity. For instance, among the guiding principles proposed to maximize carbon storage and commercial forestry in landscape restoration schemes in the tropics is that afforestation should not replace native grasslands and savannahs (Brancalion & Chazdon, 2017).

The reviewed literature suggests that governance and shifted economic incentives will be necessary to promote the development of those land-based climate mitigation activities that secure multiple ecosystem services (Grubler *et al.*, 2018; IEA & FAO, 2017; van Vuuren *et al.*, 2015; Werling *et al.*, 2014). Demand-side climate mitigation measures, e.g., reduced waste or demand for energy and livestock products, are often more likely to achieve multiple goals, such as greenhouse gas emission reduction, food security and biodiversity protection than bioenergy plantations (Grubler *et al.*, 2018; Smith *et al.*, 2013). Low energy demand pathways, with reduced or no reliance on BECCS, would likely result in significantly reduced pressure on food security (Roy *et al.*, 2018). Some demand-side changes will require life-style changes, which can take more time than supply-side measures and pose challenges to influence by policies (Smith *et al.*, 2013; see also section 5.3.2.1 and 5.4.1.2 on consumption). However, current observable trends suggest a substantial potential to decrease the global energy demand despite rises in population, income and activity. A global scenario study based on these trends suggest that the 1.5 degrees Celsius target and many SDGs could be met without relying on negative emission scenarios (Grubler *et al.*, 2018), but most global studies concluded that some negative emissions might still be necessary even with optimistic assumptions concerning, e.g., lifestyle changes, reforestation and energy transitions (e.g., van Vuuren *et al.*, 2018). Further transdisciplinary research and improved models for ecosystem management and bioenergy scenarios are, however, necessary to close the knowledge gaps outlined above.

5.3.2.3 Conserving and restoring nature on land while contributing positively to human well-being

Framing the problem

The concept and practice of protected areas (PAs) has been at the heart of conservation policy since its inception in the 19th Century. Traditionally, PAs were implemented by governments using strict conservation approaches, which treated biodiversity protection as incompatible with social-cultural practices and benefits. By the 1980s, classic conservation models evolved towards more participatory management and inclusive conservation approaches. The Convention of Biological Diversity (CBD) called for the protection of at least 17% of terrestrial and inland water by 2020, especially areas of particular importance for biodiversity and ecosystem services (a target nearly met, although with limited spatial and ecological representativeness; chapter 3).

Existing PAs suffer from several challenges. Isolated areas can lack functional connectivity for species. Some authors argue that biodiversity within PAs continues to decline, questioning the effectiveness of current conservation management approaches (Coad *et al.*, 2015), while other studies document the effectiveness of PAs, at least relative to other land uses (Gray *et al.*, 2016). Today's PAs are likely not adequate to conserve many species whose distributions will shift due to climate change (Secretariat of the Convention on Biological Diversity, 2014); they may also suffer from additional degradation (e.g., increased fire risk). In this context, to protect habitats and species and maintain connectivity, attention has been directed towards biodiversity-rich land under **private** ownership and under the governance and management of IPLCs, who already contribute to the management of around 40% of PAs globally (Drescher & Brenner, 2018; Garnett *et al.*, 2018; Kamal *et al.*, 2015; Maron *et al.*, 2018; Paloniemi & Tikka, 2008; Tikka & Kauppi, 2003).

In addition to conservation, **restoration** of ecosystems and landscapes (although in its early stages) is rapidly becoming a new major driver of changes in nature and NCP (Aronson & Alexander, 2013). Aichi Biodiversity Target 15 together with the "Bonn Challenge"—a global restoration initiative—have established a goal of restoring 150 million hectares of deforested and degraded land globally by 2020. The New York Declaration on Forests expanded this goal to 350 million hectares restored by 2030 (Chazdon *et al.*, 2017). In addition, several large-scale restoration initiatives have recently emerged around the world (Latawiec *et al.*, 2015).

What do scenarios say about how to achieve these goals?

Sustainability-oriented global scenarios usually consider the maintenance or expansion of protected areas (PA) networks as central. For instance, the Rio+20 target-seeking scenarios implemented three different assumptions regarding the extent and distribution of PAs. The Global Technology pathway, reflecting a land-sparing approach, explores the expansion of agricultural areas close to existing agricultural areas, and assumes that 17% of each of 7 biodiversity realms will be protected in PAs situated far from agriculture. In the Decentralized Solutions pathway, production areas are shared with nature elements covering at least 30% of landscapes to reinforce PAs, which cover 17% of all 779 ecoregions. As previously discussed, Kok *et al.* (2014) show that both strategies may reduce biodiversity loss, but the biodiversity preserved, and the spatial distribution of losses differ greatly (see **Box 5.1**).

Any approach entails international cooperation including funding from different sources (e.g., Global Environment Facility, Butchart *et al.*, 2015) to facilitate and scale up protected areas. This is especially true in developing regions facing challenges to effective protection in current and future protected areas. Scenarios at local and national scales emphasize, as a critical element of pathways, the improvement of monitoring systems and the enforcement (and protection) of environmental legal frameworks (Aguiar *et al.*, 2016).

Also, at local to regional scales (Appendix 5.2), scenarios show that **existing protected areas are at risk**, mostly due to political changes, incomplete implementation and institutional weaknesses (see chapter 3 for a discussion). In Latin America, for instance, the network of PAs and indigenous lands is one of the most important factors managing the Amazon deforestation frontier (Aguiar *et al.*, 2007; Pfaff *et al.*, 2015; Soares-Filho *et al.*, 2010). However, these areas suffer the impacts of illegal logging and fires, and are threatened—above all—by political and economic pressure to give way to agricultural expansion, major infrastructure and natural resource extraction projects (Aguiar *et al.*, 2016; Ferreira *et al.*, 2014).

The **expansion of protected areas networks** faces competition with other land uses. In a global analysis, Venter *et al.* (2018) found that both old and new protected areas did not target places with high concentrations of threatened vertebrate species, but instead appeared to be established to lessen conflict with agriculturally suitable lands. In Africa, for instance, although the need for expanding protected area networks is great, some authors argue that improved governance of existing PAs may provide more biodiversity benefits (Costelloe *et al.*, 2016).

Local scenarios propose a combination of protected areas and land-sharing approaches through landscape planning. The 'land sharing' strategy has the potential to improve connectivity between natural areas by boosting natural elements within the agro-ecological matrix. Meanwhile, increasing productivity reduces the land area needed for agricultural production and consequently reduces biodiversity loss. But the sustainability of that intensification depends on reserving large areas within the agro-ecological matrix for natural elements (Perfecto & Vandermeer, 2010).

The **spatial arrangement** of protected areas and natural elements also matters, as explored by landscape planning to meet human needs via multiple ecosystem services while maintaining biodiversity in functioning ecosystems. This can be done on private lands, optimizing trade-offs between environmental, social and economic benefits (Kennedy *et al.*, 2016; Seppelt *et al.*, 2013). Such planning can also consider the importance of mosaics of diverse governance types and the overlap of PAs with Indigenous lands and community-governed conservation areas that can enhance opportunities to meet human needs and ecosystem function. In the Andes, for instance, the spatial and temporal organization of farms and agricultural practices at multiple scales—including some agroforestry practices—could improve yield and boost ecosystem services (Fonte *et al.*, 2012).

Restoration

Ecosystem restoration can also deliver multiple benefits to people and help achieve multiple Sustainable Development Goals (Possingham *et al.*, 2015). Successful cases of restoration are found all over the world (see Fisher *et al.*, 2018). Achieving these targets would ease pressing global challenges such as climate change mitigation (Chazdon *et al.*, 2016) and adaptation (Scarano, 2017), and biodiversity decline (Crouzeilles *et al.*, 2017). Large-scale restoration may play a critical role in enhancing nature's contributions, but it represents yet another competing use of already scarce land resources with potential impacts on local livelihoods (Adams *et al.*, 2016; Hecht *et al.*, 2014).

Box 5 4 Restoration experiences in Brazil.

Brazil provides valuable case studies for understanding potential solutions and challenges of accommodating new restoration areas where land is an increasingly limited resource (Latawiec *et al.*, 2015). The State of Espírito Santo government, supported by both agricultural and environment departments, has been promoting large-scale forest restoration and conservation programs through the 'Reforest' Program ('Reflorestar' in Portuguese) with a total goal of approximately 236 000 ha between 2005 and 2025. At the same time, the State's development plan aims to expand agricultural areas by 284 000 ha and forest plantations by 400 000 ha. The current pasture productivity in the State is less than one third of its potential (Latawiec *et al.*, 2015). Pasturelands therefore provide an opportunity to accommodate both intensified but non-confinement-based cattle ranching activities and restoration, through land sparing **(Figure Box 5.4.A)**.

A second example is from the state of Sao Paulo, where the Rural Landless Workers' Movement redistributed more than 3000 families to settle in the Pontal do Paranapanema in 1942, in the Reserva do Pontal area designated to protect the highly threatened Atlantic Forest ecosystem and the endangered endemic black lion tamarin (Hart *et al.*, 2016; Valladares-Padua *et al.*, 2002). A concerted effort by a range of stakeholders supported rural livelihoods through landscape-level coordination, developing sustainable agroforestry initiatives and creating ecological corridors to connect forest fragments (Wittman, 2010). Diversified agroforestry created a buffer for wildlife reserves and improved agricultural productivity, increasing incomes for local communities (Cullen *et al.*, 2005). This example demonstrates that implementation of a landscape approach wherein a participatory approach can facilitate forest conservation and restoration. Such integrated landscape management approaches have gained prominence in the search for solutions to reconcile conservation and development (Sayer, 2009), particularly if they consider nonlinear ecosystem dynamics and climate change (Sietz *et al.*, 2017).

Figure 5 4 A **An example of land sparing.**

An increase in pasture productivity in areas suitable for cattle ranching (left) allowed a farmer to set aside marginal areas with rocky soils (right) for forest restoration in the Atlantic Forest in Brazil (Latawiec *et al.,* 2015). Photo credit: Veronica Maioli.

These examples reveal several essential conditions for land sparing to occur, such as covering implementation costs, providing technical assistance, and setting up rigorous monitoring to avoid leakage and rebound effects. It is also paramount to protect local livelihoods involved in other farming activities that may be less profitable but key to meeting local and regional food security needs (e.g., production of staple crops such as black beans, in the case of Brazil). As illustrated by first São Paulo example, sometimes leakage might be best avoided by diversifying production systems through land sharing (Perfecto *et al.*, 2009).

Demand for agricultural land and land for restoration will continue to grow for several decades, putting pressure on scarce land resources (Smith *et al.*, 2010). This pressure can be mitigated, however, through solutions promoting more sustainable and inclusive land management. In particular, integrated land-use planning that takes into account conservation and restoration priorities with priorities for increased agricultural production (Margules & Pressey, 2000; Strassburg *et al.*, 2017) might play a key role in reconciling competing demands.

Conservation and restoration scenarios and IPLCs

Few of the aforementioned scenarios directly address the interplay between human well-being, nature conservation and restoration goals. It is primarily at local scales that studies suggest that engaging meaningfully with IPLCs—whose lands hold much of the world's biodiversity—is one of the most effective ways to secure biodiversity conservation and sustainable use (FPPIIFB & SCBD, 2006). The global importance of IPLCs is treated in chapters 1, 2, and 3.

Empowering IPLCs as central partners in conservation and climate-change mitigation has allowed many people to gain access to land and citizenship rights (chapters 3 and 6; Kohler & Brondizio, 2017), but this has provided limited improvements in access to social services and economic opportunities. On the other hand, Kohler and Brondizio (2017) suggest that public policies and conservation programs should not delegate responsibility for managing protected areas to IPLCs without considering local needs, expectations and attitudes toward conservation.

It is primarily at local scales that scenarios explicitly consider land tenure rights, economic incentives and alternatives, and vulnerability of IPLCs (living inside or outside protected areas and other special units; e.g., Folhes *et al.*, 2015). For example, in **China**, Cotter *et al.* (2014) considered a GoGreen scenario that embedded the MAB (Man and the Biosphere Programme) principles of conservation and sustainable livelihoods while introducing Traditional Chinese Medicine agroforestry. This GoGreen scenario enabled protection of forests while sustaining rural livelihoods. Similarly, Suwarno *et al.* (2018) concluded that the current forest moratorium policy (BAU) is not effective in reducing forest conversion and carbon emissions. Furthermore, they suggested that a policy combining a forest moratorium with livelihood support and increases in farm-gate prices for forest and agroforestry products could increase local communities' benefits from conservation (including via certification schemes for cocoa production). Elsewhere, Mitchell *et al.* (2015) employed social-ecological modelling and scenario analysis to explore how governance influences landscape-scale biodiversity outcomes in the **Australian Alps**. Their study highlighted the importance of shared values and attitudes supportive of conservation, as well as political will and strategic direction from local governments.

Finally, some scenarios also explicitly mention the importance of **using biodiversity products to create economic alternatives** for IPLCs and regional economies (Aguiar *et al.*, 2016; Folhes *et al.*, 2015). A recent paper (Nobre *et al.*, 2016) brings a broader proposal: a new development paradigm that transcends reconciling conservation with intensification of agriculture, moving towards biomimicry-based development—a "Fourth Industrial Revolution" that could benefit IPLCs and the world at large.

Synthesis and open questions about conservation and restoration pathways

The expansion of the current PA network is necessary to ensure that PAs are ecologically representative and connected, including in light of climate change. However, to accommodate conservation and restoration where land is increasingly limited, the reviewed literature points out that **participatory spatial planning based on a landscape approach** is key. The landscape approach aims to allocate and manage land to achieve social, economic, and environmental objectives in landscape mosaics where multiple land uses coexist. Such integrated management should also include the urban-rural interface, and the importance of locally desirable livelihood activities less profitable than industrial agriculture, but key to meeting local and regional food security needs.

On the other hand, many existing PAs are not effectively managed or adequately resourced. The review of the current scenario literature, especially at local to national levels, underlines the need to **protect the protected areas**, including by enhancing monitoring systems and legal frameworks.

Sustainable-use protected areas (and other special areas, such as indigenous lands) will rest upon **appropriate governance mechanisms and collaboration with IPLCs.** This would begin with recognition of IPLC knowledge and leadership including via novel compensation-oriented payments for ecosystem services programs (5.4.2.1), but it also might involve economic alternatives, technological innovations, and access to markets and basic services (education, health, etc.). On the other hand, IPLCs should not be seen as "traditional environmentalists" to whom the responsibility to manage protected areas is delegated, but rather an opportunity to co-govern with those who have intimate and ancestral-derived knowledge and practices, but also varying needs in different contexts. Finally, innovations related to the benign industrial use of biodiversity could benefit local populations and regional economies, and contribute to conservation.

Mechanisms to facilitate and scale up international **financing of protected areas** are also essential, especially in developing regions. However, funding is not enough, as weak governance and power structures in different regions need to be taken into account. **Power asymmetries**, especially in developing countries, threaten not only legal frameworks (for instance, regarding protected area networks), but also the possibility of implementing integrated management processes.

5.3.2.4 Maintaining freshwater for nature and humanity

Framing the problem

Maintaining freshwater for nature and humanity is an urgent challenge, with an estimated 1.8 billion people likely to live under conditions of regional water stress (Schlosser *et al.*, 2014). The diversion of freshwater for human use has been characterised by an incomplete appreciation of freshwater ecosystems and the services they provide. Aquatic ecosystems in some cases have been losing species up to 5 times faster than other ecosystems (Ricciardi & Rasmussen, 1999), and the situation is set to worsen as anthropogenic pressures on water resources increase (Darwall *et al.*, 2008; Dodds *et al.*, 2013; Dudgeon *et al.*, 2006). Anthropogenic land-cover change is a more dominant driver of hydrological impacts than climate change (Betts *et al.*, 2015), and global-scale population and economic growth variables have greater effects on projected water supply-demand relationships than does mean climate (Vörösmarty *et al.*, 2000). Climate change is a major driver of agricultural water demand, however, primarily through increased temperature, which increases the transpiration demand; effects due to changes in precipitation and runoff are variable and uncertain (Turral, 2011).

Around 2010, food production accounted for 70-84% of global water consumption, and dominated projected consumption (FAO, 2016; Secretariat of the Convention on Biological Diversity, 2014). Implementation of the OECD baseline scenario for 2050 in modelling biodiversity "intactness" of freshwater ecosystems (Janse *et al.*, 2015) indicates further global declines in aquatic species richness, particularly in Africa. In 2014, freshwater fish (a major livelihood component and economic sector) constituted 12.7% of the global capture fishery, and 64% of aquaculture fish (FAO, 2016; McIntyre *et al.*, 2016). Access to fish by IPLCs is being eroded by changing legal frameworks and commodification (Allison *et al.*, 2012; Beveridge *et al.*, 2013), as well as pollution and overfishing. Freshwater and associated fish are critically limiting resources on many small island nations. In the Polynesian islands, as one example, major threats to freshwater biodiversity relate mainly to alteration of natural flow regimes (barriers and abstraction of water), plus overharvesting, alien species and climate change (Keith *et al.*, 2013).

Water for energy production accounted for approximately 15% of global withdrawals in 2010 (Flörke *et al.*, 2013). Fricko *et al.* (2016) found that "once-through" cooling was the dominant source of withdrawals, and of thermal pollution in thermal power generation. Meeting targets for a stable global climate through the development of renewable energy puts additional stress on freshwater systems, because hydropower is considered a major renewable energy source. Changes in river flood pulses (sensu Junk, 1989) and water quality induced by dams have had adverse effects on biodiversity, ecological productivity (e.g., Abazaj *et al.*, 2016; Arias *et al.*, 2014) and sediment transport, by decreasing wet season flows, increasing dry season flows, impeding movement of aquatic life, and trapping sediments.

Changes in land cover in catchments affect river flow characteristics. Evidence for increased run-off from deforestation is clear (Zhang *et al.*, 2017), whereas the effects of afforestation are ambiguous (Jackson *et al.*, 2013; Vanclay, 2009). Clearly there are important trade-off implications for the carbon mitigation potential of afforestation. Land and terrestrial water management also poses a serious threat to the freshwater-marine interface (Blum & Roberts, 2009). Lotze *et al.* (2006) analysed 12 temperate estuaries and coastal seas, and found that about 40% of species depletions and extinctions could be attributed to habitat loss, pollution, and eutrophication. Other important consumers of water are industries, of which mining is particularly important in terms of demand and impacts (pollution, sediment load; Azapagic, 2004; Vörösmarty *et al.*, 2013; chapter 2).

Here we summarise characteristics of pathways towards resolving these tensions and challenges at global, regional and local levels, and draw out commonalities and differences across these scales. People use water to supply domestic and urban needs, to produce food, and to produce energy. These uses consume water, change its quality, and change associated contributions to people. Most normative scenarios relating to water have focused on improving water supply and quality for human purposes. In recent years, freshwater policies "have begun to move away from a riparian rights focus … towards efficiency improvements and river basin management" (UNEP, 2002). At the global scale, this shift is reflected in the global scenario analyses, as outlined below.

What do scenarios say about how to achieve these goals?

The GEO-3 "Policy First" scenario (UNEP, 2002) emphasizes using top-down governmental policy and institutional instruments to create integrated resource management approaches, including increased environmental stewardship. This scenario also invests in governance focused on social environmental policies, and enables greater participation from the private sector. The "Sustainability First" scenario describes pathways grounded in both government and civic society taking action against declining global social, economic and environmental indicators. The pathways incorporate greater collaboration between actors, with initiatives from society pushing sustainability. They also rest on positive media engagement, incorporation of research and analysis, and increased accountability and transparency. Greater integration of regional policies related to water management and other transboundary issues are envisioned.

The GBO-4 (CBD, 2014) re-assessment of the PBL (2012) Roads from Rio+20 used the same 3 scenarios designed to attain SDG targets, but with metrics addressing Aichi Biodiversity Targets relating to inland waters. Elements of all three scenario pathways address the maintenance of freshwater ecosystems and their multiple contributions. Aside from the systemic integration of freshwater nature into planning, development and communications, GBO-4 pathways include national accounting of water stocks. Specifically, in these pathways IPLCs are involved in creating and governing protected areas (PAs), PA networks are expanded to be more representative of freshwater ecosystems, and protection is enhanced for river reaches upstream and downstream of terrestrial PAs to maintain connectivity. These pathway elements were echoed strongly by Harrison *et al.* (2016). GBO-4 included a range of other elements, including management of pulsed systems that protects refugia for aquatic biota, identification of systems important for providing multiple ecosystem services (including disaster risk reduction); reduction of pressures on wetlands, river and mountain areas, and restoration of degraded systems. Policy instruments include the enforcement of environmental regulations for development projects, and new market instruments (wetland mitigation banking, payments for ecosystem services).

Pathways for food and freshwater

Pathways towards sustaining freshwater ecosystems and their multiple contributions rest on addressing **land use**, **eutrophication** and **hydrological disturbance**. The World Water Vision (Cosgrove & Rijsberman, 2000) identified two critical pathway elements: 1) limiting expansion of agricultural land area (requiring improved water use efficiency and agronomy) and 2) increased storage, through a mix of groundwater recharge, wetlands, alternative storage techniques employing ILK, and dams that minimize disruption of flow regimes and impacts, including on IPLCs.

Pathways for energy, climate and freshwater

Fricko *et al.* (2017) found significant potential gains from technological improvements in cooling. Transitioning toward air and sea-water cooling over the period 2040-2100 could reduce cumulative freshwater withdrawal by 74%, consumption of freshwater by 19% and thermal pollution by 41%. In addition, a rapid scale-up of non-water based renewable energy generation (wind, solar) could generate multiple co-benefits, including climate stabilisation, reduced water demand, improved water quality and a reduction in hydrological disturbance, sustaining fluvial ecosystems. In the Gulf States, cogeneration (using thermal energy from electricity generation to desalinate seawater) is responsible for about 85% of desalination (El-Katiri, 2013).

Flow alteration and barriers were not explicitly addressed in the global scenario pathways assessed here. At local and regional scales, studies suggest that improving environmental legislation (Fearnside, 2015), enhancing existing infrastructure (Zwarts *et al.*, 2006), and implementing operating procedures to minimise downstream ecological impacts (Kunz *et al.*, 2013) are critical pathway elements for conserving freshwater systems and their contributions. Demand management (advocated in GEO-3 and other meta-analyses) is also a central recommendation, including improved water use efficiency, pricing policies and privatisation.

In freshwater system pathways, there are some synergies between conserving nature and NCP and mitigating climate change: restoring and avoiding further conversion of peatlands is an important pathway element (Griscom *et al.*, 2017).

Regional and local perspectives

Sub-Saharan **Africa** is expected to experience one of the largest increases in point-source pollution of freshwater due to increasing urbanization and slow development of sewage treatment (Nagendra *et al.*, 2018). Investment in wastewater treatment is crucial to complement improved sewage reticulation (van Puijenbroek *et al.*, 2015), while investment in distribution infrastructure and improved regulation of access are pathway elements to ensure equitable access to water (Notter *et al.*, 2013).

Improvement of infrastructure across the continent is needed to increase agricultural production, while improved irrigation efficiency needs better enforcement of regulations (AfDB, 2015; Notter *et al.*, 2013). In the Inner Niger Delta, Zwarts *et al.* (2006) found that improving efficiency of existing water infrastructure, instead of building new dams, would improve conservation of ecosystem services and economic growth. In southern Africa a number of studies indicate that participatory approaches to water resource planning and environmental flows could enable equitable trade-offs between water users (Brown *et al.*, 2006; King *et al.*, 2014, 2003). Operating procedures for existing hydropower dams can be optimised to reduce biogeochemical impacts downstream (Kunz *et al.*, 2013).

In the Americas, issues arising from hydropower developments have identified elements of pathways towards sustainability (Moran *et al.*, 2018). In the Brazilian Amazon, unrepealed legacy legislation has allowed the overriding of environmental licensing laws; institutions and legal instruments, and full disclosure and democratic debate on river basin development plans are critical pathway elements, especially for transboundary river systems (Fearnside, 2015; Latrubesse *et al.*, 2017). At the local level in the Brazilian Amazon, key pathways include strengthening the capacity of local communities to negotiate with developers and develop management skills for collective projects (Folhes *et al.*, 2015).

Social-ecological systems modelling by Mitchell *et al.* (2015) in south-eastern Australia in the **Asia and the Pacific** region indicates that conservation of alpine lakes, fens and bogs would be enhanced by adoption of a long-term governance regime immune to short-term political agendas.

In **Europe and Central Asia**, a participatory backcasting scenario planning process for Biscay in the Basque Country found that water supply and water regulation could be optimised under their “TechnoFaith” scenario—one which prioritizes technological solutions. The “Cultivating Social Values” scenario achieved almost the same results through participatory decision-making, emphasis on local government, responsible consumption, and a proactive society (Palacios-Agundez *et al.*, 2013).

Synthesis about freshwater pathways

The scenarios literature reviewed above coupled with broader literatures on freshwater systems and management suggest the following key elements of sustainable pathways. A central cross-cutting conclusion is that sustenance of freshwater ecosystems and their contributions requires healthy catchment areas, careful allocation of water rights and maintenance of hydrologic variability (Aylward *et al.*, 2005; Dudgeon, 2010; Durance *et al.*, 2016; Harrison *et al.*, 2016; Kuiper *et al.*, 2014; Poff, 2009; Postel & Thompson, 2005). **Foremost among pathway elements is the importance of dynamic and iterative deliberations among stakeholders** in identifying desired futures and policy to achieve these (Tinch *et al.*, 2016).

Freshwater production as an ecosystem service: The pathways reviewed secure sustained supply of good quality water sufficient for human and environmental needs. This requires protection of upstream catchment areas, middle-reach floodplain systems (Green *et al.*, 2015) and often land rehabilitation to reinstate storage and reduce erosion and sediment transport. Such efforts can be broadened to regional and continental institutional arrangements to address the impacts of land-use change at basin scales (Ellison *et al.*, 2017). Explicit recognition of the provisioning function of upstream catchments is crucial for land-use planning, a central element of sustainable pathways. Design strategies for forested catchment land cover, such as (re)planting water courses with indigenous species can also produce natural hydrographs and high-quality water (Ferraz *et al.*, 2013; Vanclay, 2009). Integration of surface and groundwater management (Giordano, 2009) reduces the need for dams. Catchment protection (e.g., limiting mining and industry) can reduce pollution of water-producing areas.

Freshwater systems: There is strong consensus that variability in hydrological regime is crucial for maintaining freshwater ecosystems and their contributions to society, as central in sustainable pathways (e.g., Annear *et al.*, 2004; Biggs *et al.*, 2005; Bunn & Arthington, 2002; Poff *et al.*, 1997, 2010; Postel & Richter, 2003). Sustainable pathways maintain or re-instate flow variability, quantity, timing and quality needed to sustain healthy freshwater systems. Pathway element include: i) slowing and reversing catchment land cover transformations (deforestation, intensive cultivation); and ii) minimising disruption of flow regimes by using fewer, smaller dams.

Agricultural production: Attaining ambitious pathway targets for agricultural production (see section 5.3.2.1 Feeding Humanity) without damaging freshwater nature entails a broad set of actions. Optimising water use for agricultural production rests on sustainable intensification, improved management through technology, better agronomy, and improved hydrological governance, including implementation of “green water” techniques (Bitterman *et al.*, 2016; Pandey *et al.*, 2001; Rockström & Falkenmark, 2015). Also important are improved management to reduce non-point source pollution (e.g., Hunke *et al.*, 2015) and sediment input to freshwater systems, and enforcement of standards and allocations.

Energy production: The production of hydropower—central to many sustainable pathways—carries many impacts which cannot be mitigated (e.g., Fearnside, 2015; Kling *et al.*, 2014). Reductions in variability, discharge and changes in biogeochemistry are among these. Alternative sources of renewable energy are implementable with present technology. Management regimes of existing hydropower dams can be optimised by integrating ecological requirements of variability and water quality into standard operating protocols (Kunz *et al.*, 2013).

Supply chains: Sustainable pathways require that supply chains secure sufficient water to meet environmental demands, human rights and needs. This can be achieved by a combination of improved valuation of the resource (demand management), involving stakeholders inclusively, and investment in infrastructure, such as dual reticulation systems for urban supply, treatment systems for urban waste water and agricultural waste water. Dedicated institutional arrangements for managing river basins are seen as a critical component for managing supply chains.

Consumer actions: Reduction of consumption and waste as a key pathway element can be achieved by optimising efficiency in urban use, agricultural use (precision irrigation, improved agronomy, reduced waste flows), industrial/mining use (tertiary treatment of waste, increased regulatory oversight) and the energy sector (transition to alternative renewables, and cooling systems). Such actions are not likely to be made without changing incentives (including water pricing) (5.4.1.1, 5.4.2.1), encouraging behaviour change including through infrastructure (5.4.1.3), and increasing awareness and knowledge among consumers (5.4.1.8).

5.3.2.5 Balancing food provision from oceans and coasts with nature protection

Framing the Problem

Seafood from fisheries and aquaculture is an integral part of the global food system, supplying approximately 17% of all animal protein consumed by humans and providing a suite of micronutrients important for human nutrition (FAO, 2016). The dietary importance of seafood is pronounced in many food-insecure regions (Béné & Heck, 2005; FAO, 2016). Demand for seafood is predicted to grow substantially in coming decades, potentially at a higher rate than other major sources of animal protein (Tilman & Clark, 2014), and failing to meet that demand may affect the health of millions of people (Golden *et al.*, 2016).

Broad limits to global marine fisheries production have been reached (Worm & Branch, 2012), while aquaculture production of aquatic animals has steadily increased over the past four decades. As of 2013, 31.4% of fish stocks evaluated by the FAO were determined to be overfished and 58.1% were fully fished (FAO, 2016); the former yield less food than is theoretically possible, and the latter cannot yield additional food without becoming overfished. While marine fisheries landings reported by the FAO have remained relatively steady since the mid-1990s, at ~80 million metric tons, aquaculture production increased from less than 10 million tons in 1985 to over 70 million tons, or 44% of the world's total seafood production, in 2014 (FAO, 2016). A recent reconstruction of global catches (including catch types excluded from the FAO data) indicate that the mid-1990s global maximum in catches was higher, and that the decline in the subsequent years has been more severe, than observed in the FAO data alone (Pauly & Zeller, 2016). While aquaculture avoids some of the ecological concerns of fisheries, concerns involve the conversion of coastal wetlands, particularly mangroves, for aquaculture (Ottinger *et al.*, 2016), and the use of the majority of the world's fish oil and fishmeal production for aquaculture feeds (Tacon & Metian, 2015).

Safeguarding and improving the status of biodiversity will entail reducing intensity of seafood production to levels that allow for sustainable use of living marine resources (Sumaila *et al.*, 2015; Worm *et al.*, 2009). Some efficiency improvements are possible, however, such as ensuring that food-grade fish are used for direct human consumption rather than for aquaculture or livestock feed (Cashion *et al.*, 2017). While indirect drivers such as demographic changes and consumption patterns increase pressures on marine biodiversity, these drivers also exacerbate other factors such as poor governance and poverty (Finkbeiner *et al.*, 2017). When fisheries resources are overexploited, actions to improve conservation status can also increase sustainable seafood production. However, conservation and fisheries rebuilding may affect the availability and access to living marine resources by specific human communities in the short-term, although effectively managed marine ecosystems can support long-term sustainable development (Costello *et al.*, 2016; Jennings *et al.*, 2016; McClanahan *et al.*, 2015). Involvement and participation of stakeholders and local communities and consideration of local traditions in decision-making and implementation of resource management and biodiversity conservation policies could help reduce trade-offs between seafood provision and biodiversity conservation (Berkes, 2004; Christie *et al.*, 2017; Uehara *et al.*, 2016). Meeting food provisioning objectives appears to entail conservation and/or restoration of marine ecosystems, reduction of pollution, management of destructive extractive activities, strong progress toward climate change targets, elimination of perverse subsidies, education and other aspects of capacity builiding (Teh *et al.*, 2017).

What do scenarios say about how to achieve these goals?

Available scenarios for marine biodiversity and ecosystem services focus on identifying and exploring pathways to achieve biodiversity conservation and sustainable seafood production goals across multiple spatial scales (Table SM 5.2.A). Specifically, these scenarios explore options for marine protected areas and fisheries management such as spatial planning and control of catches or fishing effort. Climate change and its effects on marine biodiversity and ecosystems are included in a few cases to examine how regional conservation and fisheries management goals can be achieved under global changes.

Marine pollution is a cross-cutting issue that is often implicitly included in scenarios related to multiple economic sectors. Some of these sectors are sources of marine pollution. Marine spatial planning processes are central, managing activities such as shipping and coastal development. With recent focus on plastic waste in the ocean (e.g., see chapter 4), scenarios have been developed for waste management to achieve targets for marine plastic waste (Löhr *et al.*, 2017). A variety of telecouplings were explored particularly in management of transboundary fish stocks (Carlson *et al.*, 2018). For example, different fisheries management measures in the high seas on straddling fish stocks were examined to investigate their effectiveness in reducing climate risk on coastal fisheries and biodiversity (Cheung *et al.*, 2017).

Regional to global scale scenarios often focus on examining a specific policy pathway, while multiple pathways are more commonly considered at subnational to national scales (Table SM 5.2.A and Figure SM 5.2.A). At large spatial scales, existing scenarios explored different extents and configurations of marine protected areas and their effectiveness in protecting biodiversity from impacts of multiple human activities, or management of fishing effort to maximize sustainable seafood production. Although these scenario pathways are not considered simultaneously, they may indeed be mutually compatible in comprehensive pathways to sustainability. In contrast, scenarios for smaller spatial scales often examine pathways to specific national or regional policy frameworks such as the Marine Strategy Framework Directive in the Europe Union or, more generally, ecosystem-based management. These policy frameworks involve multiple policy goals, e.g., biodiversity conservation, economic benefits, sustainable food production, and the viability of specific industries or sectors. Examining a portfolio of pathways and options to achieve these multiple policy objectives and their associated interactions and trade-offs could help inform ecosystem-based management of the ocean.

One of the linkages between marine biodiversity and sustainable food production goals that is most commonly explored in existing scenario analyses (specifically target-seeking/policy-screening) is pathways to achieve Maximum Sustainable Yield (MSY) and the implications for biodiversity (see 5.3.2.5). Although direct utility of MSY as a target for fisheries management has been widely criticized (Berkes *et al.*, 1998), MSY is explicitly stated as an aspiration in important international agreements and national policies such as the United Nations Law of the Seas and and the European Common Fisheries Policy. However, achieving ecosystem-level long-term average maximum production may lead to overexploitation or depletion of relatively less productive or less valuable populations (e.g., through bycatch), which has been suggested in scenario assessments at global, regional and local scales (Cheung & Sumaila, 2008; Walters & Martell, 2004; Worm *et al.*, 2009). In some heavily exploited systems, achieving maximum sustainable yield may require restoring ecosystems and rebuilding fish stocks, which would have co-benefits for biodiversity conservation (Cheung & Sumaila, 2008; Pitcher *et al.*, 2000). In some specific cases, overexploitation has resulted in structural change in fisheries social-ecological systems, resulting in more intense trade-offs between maximizing sustainable yield and improving biodiversity status (Brown & Trebilco, 2014; Hicks *et al.*, 2016). For example, in eastern North America, the rise of invertebrate fisheries (e.g., shrimp) after the collapse of Atlantic cod may be due to a shift from a predator-controlled system to a prey-controlled system (Baum & Worm, 2009). Because of the high productivity and economic value of the invertebrates, rebuilding of cod fisheries (a potential biodiversity or ecosystem target) may lead to reduced fisheries profits (a sustainable food production target).

Achieving marine protected area (MPA) targets should contribute positively to both biodiversity conservation and sustainable food production, although the extent of co-benefits would depend on timeframe, site selection, and design and effectiveness of the protected areas. Scenario modelling efforts for MPA targets focus strongly on site selection with a primary objective of biodiversity conservation. Across many contexts, scenario and modelling studies that evaluate different MPA designs and the pathway to achieving MPA targets generally suggest that MPA networks would benefit both biodiversity and fisheries in the long-term, particularly in overexploited ecosystems, in part because of demonstrated spillover effects by which effectively-managed MPAs boost fisheries in surrounding waters (Gill *et al.*, 2017). However, trade-offs often exist in the short-term because of the time lag in biological responses to protection relative to the immediate cost of losing resource use opportunities (Brown *et al.*, 2015). The degree of such trade-offs and co-benefits is shown to be sensitive to ecosystem and MPA attributes such as mobility of organisms, dispersal of the populations, size of and connectivity between protected areas (Gill *et al.*, 2017). In addition, scenario analysis, particularly those with stakeholders participation, often reveals trade-offs and conflicts between different sectors and communities in identifying pathways to achieve the MPA targets (e.g., Daw *et al.*, 2012). Climate change may further complicate the trade-offs between MPA designation and different sectors as range-shifts and habitat changes driven by climate change may add additional constraints on the design of

MPA network or require bigger MPAs (Fredston-Hermann *et al.*, 2018). On the other hand, scenario analysis at multiple scales could also help identify pathways to reduce or resolve such trade-offs (IPBES, 2016).

Scenario research has also identified co-benefits from addressing other non-fishing drivers such as climate change (and ocean acidification) and habitat degradation. Given the increased focus on ecosystem-based fisheries management (Link, 2010), recent scenario analyses explored multiple drivers that cut across marine biodiversity and sustainable food production, including environmental change drivers (e.g., climate, pollution and habitat degradation). Overall, clear co-benefits exist in addressing drivers of environmental change for both biodiversity conservation and fisheries production globally (e.g., Cheung *et al.*, 2016) and regionally (e.g., Ainsworth *et al.*, 2012; Sumaila & Cheung, 2015). Specifically, climate change is likely to trigger species turnover and decreased potential fisheries catches, which compromises both biodiversity conservation and food production (Cheung *et al.*, 2009; Worm *et al.*, 2009).

Resolving apparently competing targets in sustainability pathways appears to require other actions with co-benefits for each. For instance, addressing perverse incentives associated with subsidies is a key element of sustainable pathways, given its co-benefits for biodiversity and long-term food provision (Pauly *et al.*, 2002; Sumaila *et al.*, 2010). Outside of fisheries management, organic and inorganic pollution are doubly harmful, often leading to hypoxia and increased harmful contaminants in seafood (e.g., mercury). Thus, achieving targets that address these climate and pollution drivers is an important element towards achieving both biodiversity and food security targets. However, few scenario analyses explore the contributions of mitigating these drivers for achieving biodiversity and fisheries targets. This is particularly relevant for climate change mitigation given that reducing biodiversity loss and/or ensuring sustainable food production (e.g., by eliminating overfishing, protecting habitat, and protecting local access to seafood) could be cost-effective means to reduce the impacts of climate change (Gattuso *et al.*, 2015).

Synthesis and open questions about pathways for oceans

Conservation and restoration of marine ecosystems can contribute positively to meeting food security goals in the long-term (Singh *et al.*, 2018). Marine conservation includes effective management of fishing and other extractive activities, consideration of climate change mitigation and adaptation, and reduction of pollution and other human pressures on marine ecosystems. International conventions and agreements exist to facilitate the development of specific actions at regional and national levels to achieve specific conservation targets and goals (Rochette *et al.*, 2015). Ultimately, a portfolio of measures is often key to reduce pressures on marine ecosystems (Edgar *et al.*, 2014).

Scenarios rarely consider explicitly the co-benefits and interactions between meeting conservation and food security goals, particularly for vulnerable coastal communities (McClanahan *et al.*, 2015). Recent studies, mainly at regional to local scales, have started to explore conservation-food security interactions using scenario analysis **(Table SM 5.2 A)**. Initiatives are underway to further develop capacity for scenarios and models for marine biodiversity and ecosystem services, including collating global and regional datasets for drivers such as fisheries catch and oceanographic changes, e.g., the Fisheries and Marine Ecosystems Impact Model Intercomparison Project (Tittensor *et al.*, 2018). Specific actions being considered in pathways to achieve both conservation and food security goals include, for example, elimination of perverse subsidies, reduction in fishing capacity, alternative fisheries management, designation of marine protected areas and climate mitigations. However, given the increasing focus of international conservation efforts on large marine protected areas or co-management of natural resources beyond national jurisdictions, linking scenario exercises with global scale pathways would help elucidate co-benefits and trade-offs of conservation efforts with food security issues locally, nationally and globally.

5.3.2.6 Resourcing growing cities while maintaining the nature that underpins them

Framing the problem

Urbanization rates, while relatively stable within developed country contexts, are increasing at an unprecedented scale within developing countries of the Global South (CBD, 2012; Nagendra *et al.*, 2018). Urbanization is both the movement of people from rural to urban areas, and a function of population increases within these regions. Urban dwellers now exceed 50% of the global population, and by 2050, there will be 2 to 6 billion more of them (UN, 2012). Urbanization will drive land-cover change both within defined city boundaries and in the broader surrounding landscapes from which cities are resourced. City expansion into surrounding areas is happening more rapidly in developing countries, and population growth appears to be a key driver here. In developed country contexts urban growth and expansion is slower and more strongly correlated with GDP measures and economic growth (Seto *et al.*, 2011). Cities are major consumers of natural resources and are highly reliant on regulating functions provided by ecosystems. These resource and ecosystem dependencies can stretch over extensive areas and form the basis of telecoupled systems where trade flows of resources connect distant regions (Fang *et al.*, 2016). And despite trade flows, cities face real challenges to maintain crucial resources, including clean water (Schlosser *et al.*, 2014).

Rapid urbanization is driving extensive changes in land cover and land use. This landscape fragmentation alters biodiversity patterns and ecosystem functions (Aronson *et al.*, 2014; Foley *et al.*, 2005; McKinney, 2006; Miller & Hobbs, 2002). Growth within and on the margins of cities can overlap with areas of rich biodiversity and natural resources (Chapin III *et al.*, 1997; McDonald, 2008; Ricketts & Imhoff, 2003). Rapidly urbanizing cities in biodiversity hotspots (such as Cape Town, South Africa) are particularly vulnerable to extinction and loss (Holmes *et al.*, 2012; Seto *et al.*, 2012a).

There is a pressing need to understand the implications of loss of species and habitats in and around cities (Grimm *et al.*, 2008), in terms of ecosystem services, human well-being and equity issues. How cities are provisioned with ecosystem services now and in the future relates to the success reaching the SDGs, particularly SDG 11 (to make cities inclusive, safe, and resilient and sustainable) and SDG 15 (protecting, restoring and promoting the sustainable use of terrestrial ecosystems).

What do scenarios say about how to achieve these goals?

Local scenarios and pathways related to nature, urbanization and sustainable development

A wealth of biodiversity can exist in cities (CBD, 2012), which is important for human health and well-being, livelihood opportunities, heat mitigation, and spiritual and cultural values. Developing in a manner that secures this can be extremely difficult to achieve in cities with high levels of endemic biodiversity and pressing social needs, such as housing (e.g., Cape Town, South Africa; O'Farrell *et al.*, 2012). Informality, witnessed through sprawling collections of informal dwellings, is one such key issue and characterises rapid urbanization observed across the Global South. The widespread presence of informality highlights the local realities of poverty, a lack of urban planning and the limited capacity to shape local landscape outcomes. Schneider *et al.* (2012) note the importance of understanding local ecology in determining the role and the impact of urban form both within the city and beyond it. Their work speaks specifically to urban density, water and food relationships, and shows the negative impacts of urban sprawl for biodiversity, productivity, and local ecology. Güneralp *et al.* (2013) note the local impacts of shifting towards meat-based diets within urbanizing areas.

The Cities and Biodiversity Outlook (CBD, 2012) highlights the importance of local knowledge in underpinning urban planning and resource management. Ahrends *et al.* (2010) produced models that demonstrate the role of markets on the degradation of resources within an African city context. Weak governance fails to secure the integrity of local biodiversity resources, allowing continued erosion of public goods. Detailed place-based knowledge and modelled futures around urban projections (Güneralp & Seto, 2013) can be used to inform appropriate local policy development pathways towards sustainable futures. These should include a detailed understanding of infrastructure, incentives and disincentives to promote benign development patterns that simultaneously promote conservation. Contemporary local form in many cities presents opportunities for land managers and decision-makers to improve urban design. Combined with a systemic understanding of nature and its contributions to people, this will allow for effective sustainable planning.

One pivotal policy domain with likely long-term impact on future scenarios relates to the initial choice about local and regional road network structures (Barrington-Leigh & Millard-Ball, 2017; Marshall & Garrick, 2010; Seto *et al.*, 2014). This choice about the configuration and location of road networks is a near-permanent commitment, as compared with other aspects of physical urban form and urban land use. Road networks underlie and constrain all other aspects of urban form, which in turn affect GHG emissions, energy intensity, community activities, and resource use through travel, consumption, extraction and home production patterns (Barrington-Leigh & Millard-Ball, 2015). In addition, high-connectivity, grid-like road networks are conducive to high-density settlement, while low-connectivity road networks are highly resistant to densification. Ensuring all new road networks are highly connected will impact the extent of habitat loss during late phases of urbanization. Prominent ongoing trends in transportation infrastructure present both threat and promise for resource impacts of cities. The electrification of transport promises higher efficiency (lower resource use) but possible rebound (more travel and sprawl). Automation of transport may exacerbate preferences for low-connectivity street-network sprawl, but may also encourage vehicle sharing and free up the large fraction of city space currently used for parking, providing opportunities for improving and reimagining use of urban space.

Regional scenarios and pathways related to nature, urbanization and sustainable development

Regional trends and informants: While urban land-cover area is set to increase, how and where urban areas will expand remains unclear. Work by Seto *et al.* (2012a) on regional influences shows that population growth, international capital flows, informal economies, land use policies, and transportation costs are all important driving factors. These influencing factors vary regionally with variable outcomes, however the regions of greatest anticipated urban expansion are Africa (particularly sub-Saharan), Asia and Latin America. Regional understandings show some shared trends, but also regional variance. Expansion in Africa is likely to emerge in the form of growth in smaller towns, while Asia shows tight coupling between urban expansion and economic shifts, and in Latin America urbanization is characterised by persistent socio-economic disparities (CBD, 2012). In contrast some regions of the Global North are experiencing urban depopulation. In their analysis of national and regional models relating to food production and urban expansion, Nelson *et al.* (2010) found variable impacts on biodiversity and ecosystem services, with various influences and trade-offs at different scales, highlighting the need to consider regional effects in local decision-making and vice versa.

Regional threats to biodiversity

Scenario modelling exploring the relationship between urbanization and protected areas and biodiversity hotspots shows alarming encroachment by cities into these key biodiversity areas, with regional variation. Güneralp and Seto (2013) tracked and modelled urban growth and demonstrate that urban areas are increasing in proximity to protected areas. McDonald *et al.* (2008) reiterate this finding and serve to refine the distances and related impacts between growing cities and adjacent, previously distant, protected areas. The most rapid urban expansion in relation to adjacent protected areas is found in China, while in South America rapid urban expansion also threatens biodiversity hotspots (critical biodiversity areas without formal protection status). Forecasts consistently show overlaps between predicted areas of rapid urban expansion and intact natural habitat and biodiversity, with protected natural assets experiencing increased pressure (McDonald *et al.*, 2008). Also evident here is the variation in regional conservation approaches. Landscape perspectives are required and in this respect we can learn much for scenario modelling from both agriculture and conservation science (Schneider *et al.*, 2012).

Global scenarios and pathways related to nature, urbanization and sustainable development

Linking urban form to sustainable development

Modelled urban scenarios show likely global trends where urban land cover expansion exceeds urban population growth, highlighting the importance at the global scale of considering biodiversity management as an imperative in urban planning. Scenarios by Fragkias *et al.* (2013) suggest that between 2000 and 2030 a 70% increase in urban population will be matched by a startling 200% increase in urban cover, and that 50% – 60% of the total urban cover in 2030 will be built post-2000. McDonald (2008) makes the incontrovertible connection between urban form and per capita resource consumption, demonstrating that urbanization has profound and prolonged implications for oil consumption and climate change, such that new urban design is critically important. Ever-improving understanding of the relationships between existing urban forms and biodiversity can be effectively used to guide future urban design and development for improved sustainability.

Economic flows and telecouplings

It is increasingly recognized that global economic forces play a significant role in determining local urban form and land-cover change. In their footprint analysis, Folke *et al.* (1997) demonstrate how Baltic cities are embedded in a web of connections that stretch far beyond their own immediate environment. These cities from the Global North import and consume from distant regions without a sense of the associated ecological impacts. Folke *et al.* (1997) go on to argue that the economic forces that govern these telecouplings fall beyond the sphere of influence of ordinary citizens. Telecouplings between cities and other areas are very common, as through the provision of water and other resources (Deines *et al.*, 2016; Liu *et al.*, 2015b; Seto *et al.*, 2012b; Yang *et al.*, 2016). The flow of financial capital itself in the form of tax havens is responsible for fuelling much distant environmental degradation, including illegal fishing (Galaz *et al.*, 2018). Understanding telecouplings can help develop appropriate policies that are more equitable and just towards pathways for sustainability (Schröter *et al.*, 2018).

Synthesis and open questions about pathways for cities

The scenarios literature reviewed above coupled with broader literatures on city impacts and ecosystem services suggest the following key elements of sustainable pathways. A central element of sustainable pathways for cities (as in SDG 11) is maintaining nature and its contributions to people within cities and their broader regions (Folke *et al.*, 2009; Russell *et al.*, 2013), and broad access to those contributions, recognizing the multiple and diverse values of city residents (Pascual *et al.*, 2017a). To achieve sustainable development objectives within cities and ultimately develop sustainable cities requires critical engagement across multiple sectors, and a keen understanding of the challenges and action required at local, regional and global scales (Schröter *et al.*, 2018).

At local scales, city-specific thresholds are crucial for retaining species and ecosystem, and for pathways to achieve acceptable levels of urban transformation (CBD, 2012). This is especially difficult in biodiversity-rich areas in developing city contexts (O'Farrell *et al.*, 2012). Linked to this are the needs to strengthen local governance in order to secure public goods, and to enable transdisciplinary planning at local levels such that sectors and departments are bridged and society and businesses are engaged. Such engagements appear fundamental to shaping sustainable urban areas and guiding local-level resource consumption patterns (CBD, 2012).

Facilitating the local realization of global targets for sustainable urban development entails recognizing the emergent differences between and within regions, and the drivers of these (Seto *et al.*, 2012a). Several drivers are key: economic policy and processes, financial underpinnings, infrastructure, investment, and population growth (Seto *et al.*, 2012a). An understanding of how these key drivers impact biodiversity areas (such as protected areas) would be instructive. In particular, cities can work to ensure that biodiversity areas do not become isolated through incompatible surrounding land uses, and that city expansion considers the degree to which encroachment towards these key regional biodiversity sites can be tolerated (Güneralp & Seto, 2013).

Cities play a central role in global pathways because increasing urban land cover affects consumption of resources, including fossil fuels, which in turn propel climate change (Fragkias *et al.*, 2013). Efforts to follow sustainable development pathways within urban areas will thus benefit from a clearer understanding of telecouplings that drive patterns of production, consumption, transportation and disposal, which in turn create and entrench the spatial and social configurations of our cities. This global understanding can then in turn be used to guide local level policy formulation where negative effects are countered and where functioning ecosystems are enhanced alongside their contributions to people (Schröter *et al.*, 2018).

5.3.3 Conclusions from the scenario review

The nexus-based analysis has revealed that no single strategy will yield sufficient transformation to sustainable development and achieve multiple SDGs. All foci suggest that successful pathways entail various measures and instruments applied in concert at local, regional and global scales. All six foci involve trade-offs between sectors and groups, such that compromises are inevitable as conflicting objectives are balanced. However, the six foci also identify potential synergies where some actions have benefits across multiple objectives and for many groups. Here we synthesize five cross-cutting insights from the scenario review, which structure section 5.4 on constituents of pathways to sustainability and are taken up also in the discussion of policy options in chapter 6.

Consumption patterns are a fundamental driver of material extraction, production, and flows, but they too are driven—by worldviews and notions of good quality of life. Addressing aggregate consumption is a central theme in pathways for all foci, but some aspects are more explicit in some than others. For example, although it is aggregate consumption that drives resource extraction and production, research on scenarios and pathways more commonly addressed per capita consumption and waste than population. Similarly, scenario studies quite commonly mentioned the preferences, value systems, and (less often) collective notions of a good quality of life as drivers of consumption, but these aspects were generally not modelled explicitly (See 5.4.1.1 about visions of a good quality of life, and 5.4.1.2 about consumption).

Behaviour change pervades all aspects of transformative change—supply chains and their ecological degradation, but also conservation and restoration. Consumption is effectively a problem of habits and behavioural norms, but so too are changes in practices of production (e.g., agroecological practices in farming), conservation and restoration. All six foci identified such behaviour change as central, but scenario studies varied greatly in the detail with which they envisioned enabling this change. Many studies appealed to a combination of incentives and awareness raising, even though the latter is generally regarded to be a weak enabler of behaviour in relation to infrastructure and consistency with value systems (See 5.4.1.3 about values, agency, and behaviour).

Inequalities and inclusiveness are key underlying problems—good planning helps, but power disparities remain an issue. Across the six foci, many studies highlighted the crucial importance of addressing inequalities and involving people in participatory planning, including the urban poor and Indigenous Peoples and Local Communities. But only a few really addressed the barriers to transformative change that arise from substantial inequities in power, e.g., in the food system, where studies highlighted the difficulties posed by corporate control of seeds, agricultural inputs, and food distribution. The same issues are likely equally important in other foci, e.g., industrial fishers and seafood distributors, but were not discussed explicitly in the studies we found (See 5.4.1.4 about inequalities, and 5.4.1.5 about inclusiveness in planning and conservation).

Larger structural issues underpin all of the above factors—telecouplings, technology, innovation, investment, education and knowledge transmission. Key elements of these structural factors were often largely implicit in pathways analyses, despite their fundamental importance to behaviour change, the dynamics of global social-ecological systems, and the SDGs. The distant effects of local actions caused by telecouplings were central to the cities focus, and implicit in all of the others (e.g., via spatially disjunct supply and demand). Many studies across several foci discussed the potential gains from the spread of beneficial technologies (e.g., the climate mitigation focus), but fewer directly addressed the challenges posed by spread of harmful technologies, or the importance and design of innovation systems that encourage benign technology. Education and knowledge transmission were often addressed in scenarios directly in the form of awareness raising for particular behavioural changes or technology transfer, leaving mostly implicit the crucial roles of education systems for ensuring well-functioning participatory processes (including political ones), and of the transmission of ILK for maintaining local capacities for stewardship (See 5.4.1.6 about telecoupling, 5.4.1.7 about technolgy, innovation and investment, and 5.4.1.8 about education and knowledge transmission).

Sustainability pathway analyses indicate the importance of governance instruments and approaches such as incentives, adaptive management, law and its enforcement. There was near universal acknowledgement of the importance of several governance instruments and approaches, but much more attention to some aspects than others. For example, many studies across all foci appealed to the importance of economic incentives, but generally from a simple behaviourist perspective (as in psychological approaches) without explicit recognition of how incentive programs also effect change by articulating values (as noted in broader social science approaches). Management and governance approaches were commonly discussed as managing several sectors together (integrated management), but much less frequently discussed for early action to address emerging threats (precaution) or managing for resilience and adaptation (these are more explicit in the freshwater realm). Many studies across all foci identified particular environmental regulations, but fewer explicitly considered consistency of monitoring and enforcement although this is often crucial and implicit in scenarios (See 5.4.2.1 about incentives, 5.4.2.2 about integrated management, 5.4.2.3 about precaution, 5.4.2.4 about governing for resilience, and 5.4.2.5 about law and its enforcement).

5.4 KEY CONSTITUENTS OF PATHWAYS TO SUSTAINABILITY: ADDRESSING THE INDIRECT DRIVERS OF CHANGE

The scenario analysis in 5.2 and 5.3 demonstrated that pathways to achieve SDGs and biodiversity targets imply fundamental changes from current trends in all of the world's regions. They are in one sense extremely ambitious, while also necessary and apparently feasible. This scenario analysis also provides key insights about the pathways to realizing the full suite of goals for biodiversity and ecosystem services, but it is not a sufficient source for such insight. Our analysis revealed that some of the issues considered in the literature as central to social-ecological transitions and transformations were largely implicit or even absent in many of the target-seeking and sustainability-oriented scenarios we consulted, such as the role of formal and informal institutions, and other indirect drivers (chapter 2). Following this insight and to characterize the constituents of sustainable pathways comprehensively, the sections below interweave evidence from the scenario analysis (5.3) with evidence from diverse literatures (including those discussed in 5.2.1).

We organize this synthesis of key constituents of pathways to sustainability via eight points of leverage for social-ecological change, and five types of interventions or 'levers' of institutional change for sustainable pathways. These key points of intervention in social-ecological systems can be thought of as 'leverage points' (Abson *et al.*, 2017; Meadows, 2009), while 'levers' are management or governance interventions to effect the transformative change that achieves the collectively agreed-upon objectives for nature and its contributions to people. Note that we use the notion of 'lever' metaphorically, recognizing that global systems—as complex social-ecological systems—cannot be manipulated as neatly as can a boulder with a stick. Rather, we use 'lever'/'leverage point' to illustrate only that these levers and leverage points offer crucial opportunities to engender changes in economies and societies towards achieving shared goals.

Second, levers and leverage points are independently important: the five levers pertain more broadly than the eight leverage points, and other tools may be needed to achieve desired changes in the leverage points. The pathways we identify involve considerable flexibility in *how* to, for instance, promote positive changes in leverage points such as consumption or inequalities. Chapter 6 provides the needed account of policy options for intervention at these specific points. Our five levers, meanwhile, are intended to suggest general and systemic interventions; they are policy tools or governance approaches that are themselves key constituents of social-ecological transitions, to be considered broadly, simultaneously addressing many leverage points and social variables. There are no governance panaceas for social-ecological sustainability (Ostrom, 2007).

Change in any of these levers and leverage points may appear difficult to achieve, but we argue that many are easier to achieve in sets. Change in one aspect may enable change in others (5.4.3 details several nation-scale case studies). For example, changes in laws and policies will enable and underpin changes in management, consumption, and other aspects of behaviour. The reverse is also true: changes in individual and collective behaviours and habits can facilitate changes in attitudes, policies, and laws. Because of these bidirectional influences, there is no one way to order the levers and leverage points. Here we present the leverage points in an order that proceeds clockwise around the outside of the IPBES conceptual framework, spiralling into institutions at the end; levers are ordered from most labile to most lasting and structural (i.e., incentive programs are most easily changed, law hardest) **(Figure 5.7)**.

The analyses of leverage points and levers are organized into three sections. The first section examines each of the identified leverage points as they relate to important dimensions of global social-ecological systems (5.4.1), while the second section discusses levers of change (5.4.2). Each subsection within starts with a statement of the leverage point or lever, followed by any needed *Background*, *Evidence* and a brief discussion of *Possible points of action* (with more detail found in chapter 6). The last section provides examples illustrating leverage points and levers in action, both via national case studies and potential alternative routes that proceed from the bottom up (5.4.3).

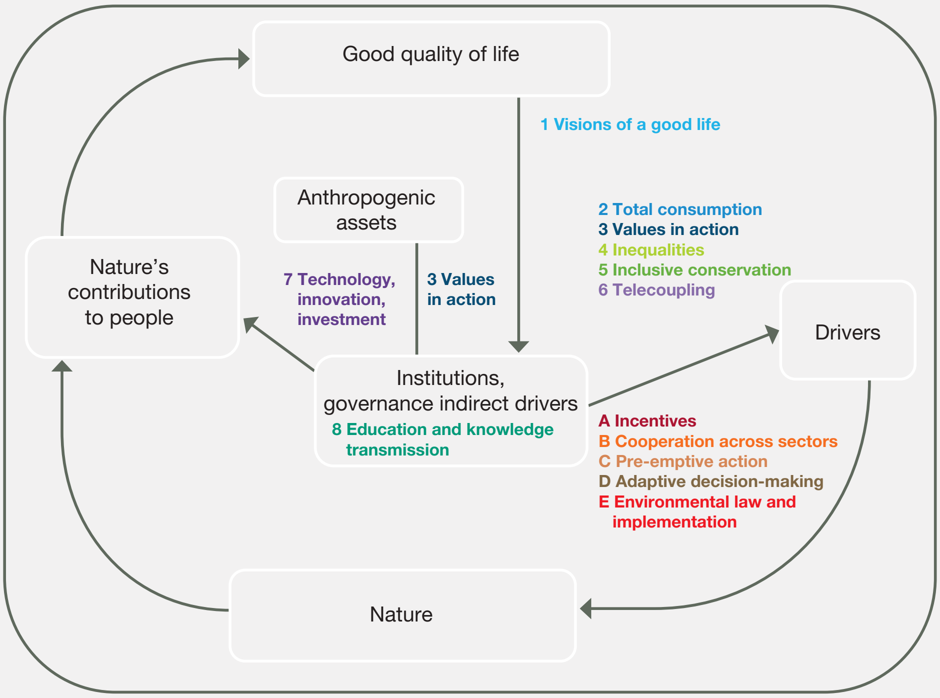

Figure 5 7 **Eight featured leverage points and five levers of transformative change toward sustainable pathways, overlaid on a simplified version of the IPBES Conceptual Framework.**

The leverage points (numbers) and levers (letters) vary in many dimensions, but each has the property that a relatively small change could effect a large change in outcomes for nature and its contributions to people. Change in one leverage point or lever can in many cases also help change others e.g., a change in visions of good quality lives (1) could greatly enable changes in consumption (2). All pertain somewhat to human formal and informal institutions, and in most cases the relationships of these institutions with other elements of the conceptual framework (in particular all five levers could be situated within the Institutions bubble, but they do pertain especially to direct drivers). Figure text for levers and leverage points differs slightly from the subsection headings, for brevity.

5.4.1 Leverage Points for Pathways to Sustainability

5.4.1.1 Visions of a good quality of life and well-being

One of the key drivers of the overexploitation of nature is the currently popular vision that a good life involves happiness associated with material consumption (5.4.1) and success based largely on income and demonstrated purchasing power. However, as communities around the world show, a good quality of life can be achieved with a significantly lower impact on natural resources and ecosystems. Alternative conceptions of a good life can be promoted without paternalism, by valuing and providing the personal, material, and social conditions for a good life with a lower material impact, and leaving to individuals the choice about their actual way of living. In this respect, the renaissance of more relational notions of well-being may be key to achieving nature-based targets. By highlighting the importance of relations to other human and non-human others for a good life we might not only contribute to decoupling consumption and well-being, but also enhance quality of life.

Background

In the academic literature, different terminologies are used to address well-being, happiness, and the good life. In general, 'happiness' refers to self-reported assessments, in which people are asked to articulate via qualitative or quantitative surveys their satisfaction with their own life. 'Quality of life' usually refers to objective indicators (such as the HDI—Human Development Index) that aggregate different data about some essential components of a dignified human life (such as life expectancy, morbidity, education & literacy, inequality). The term 'good life' is more comprehensive and includes the ancient concepts such as "eudaimonia" or "buen vivir", implying in their own way satisfaction with one's own living conditions, aspirations, and meanings, while considering collective and personal principles and virtues (see chapter 1). All these concepts (or philosophies) refer to 'agency', i.e. the ability to decide about how to live according to one's own core values (Sen, 2009). Other than preferences, which are often arbitrary and causal, core values based on deeply held beliefs and guiding principles operate as the basic points of orientation for actions and decisions. Core values can be articulated and justified to others. The concept of a 'good life' is thus linked to forms of justification and claims of justice and goes beyond immediate preferences or feelings of satisfaction.

Approaches to assessing well-being through only objective or subjective measures have generally suffered from criticism. Focusing only on resources underplays the fact that availability of resources does not ensure that they are converted into actual well-being (Nussbaum, 2003). Not only personal differences, but also environmental, institutional, and cultural conditions influence the way in which resources contribute to a good life. Focusing only on self-reported assessments gives insight into what people subjectively consider important for happiness (Layard, 2005), but, if not combined with objective indicators (Happy Planet Index; Bhutan Gross Domestic Happiness Index), it neglects the influence of external factors in determining self-assessment; it might also overlook forms of oppression (self-reported happiness can derive from ignorance of possible alternatives or entitlements, or as a coping strategy under distress). Moreover, people can decide to act according to other motives (altruism, care, etc.) against their personal happiness or advantage, thus following core values in the sense described above.

It is contested how material wealth and growth per capita correlate with (subjective or objective) well-being. While some studies show that, after a certain threshold additional wealth yields diminished happiness returns or decouple from quality of life (Binswanger, 2006; Easterlin *et al.*, 2010; Helliwell *et al.*, 2012; Jackson, 2009; Layard, 2005; Max-Neef, 1995), other recent studies contest these findings (Ortiz-Ospina & Roser, 2017; Veenhoven & Vergunst, 2014). Relative to average or aggregate income, inequality seems to have a larger negative impact on subjective and objective well-being (Oishi & Kesebir, 2015; Wilkinson & Pickett, 2010). It is widely agreed that there is no automatic or obvious correlation between wealth and well-being, but that it depends strongly on institutional, social, and cultural settings that guarantee essential conditions to achieve a good life.

Given the great diversity of conceptions of a good life and well-being, it is important to focus on the *conditions* for leading a good life rather than on the ways in which people actually (choose to) live their lives (Nussbaum, 2000, 2003; Sen, 1999). Such a focus on conditions avoids problems of paternalistic intervention (influencing or forcing people into choosing a specific conception of a good life). A plurality of options for actualization is available once the basic conditions for a good life are guaranteed. Attention can then focus on what process, group, or institution has the legitimate authority to decide what people have reason to value (Deneulin & Shahani, 2009), and to the substantial conditions for participation, including domination structures, actual access conditions, and effective 'power' to be heard and make a difference. Institutions play a key role in framing enabling conditions for a good life. Experiencing life in an environment devoid of dangerous impacts such as those associated with global warming, can be considered a 'metacondition' ('ecological functioning capability'; Holland, 2008; Page, 2007).

Conditions can be *subjective* (preferences), *objective* (material or institutional), and *intersubjective* (social or cultural) (Muraca, 2012). For example, affording shoes can be considered as a subjective condition for happiness (if one loves shoes, collects them, etc.), as an objective condition for being, say, healthy (especially in cold countries), and/or as an intersubjective condition for leading a good life in the face of others in a society, in which wearing shoes is considered a symbol for decency and reliability (Sen, 1987).

When addressing policy interventions about well-being, intersubjective conditions are often neglected, although they play a crucial role especially for change in consumption patterns. Overconsumption is often not only a result of subjective preferences, but also of infrastructural or cultural conditions. For example, if everyone else drives a sports utility vehicle (SUV), driving a small car on the highway is not only a matter of social status but also of personal safety. Having a smartphone up to date is increasingly a necessity for work, but also for access to health services or for social interactions. Such social conditions depend on cultural patterns that influence and are influenced by institutional framing.

Evidence

The orientation towards ways of living based on high material and energy flows is supported by shared values that promote happiness as based on material consumption and success demonstrated mainly via purchasing power and economic status. This model supports what has been termed an 'imperial mode of living' that arguably stabilizes the economies of developed nations while offering a hegemonic orientation to developing countries (Brand & Wissen, 2012).

Since concepts of the good life are influenced by institutional settings and social expectations, social and institutional change can foster alternative conceptions of a good life and guarantee prosperity (Jackson, 2009) with lower material impacts on resources and ecosystems (Røpke, 1999) if combined with the promotion of the fundamental conditions for guaranteeing flourishing (Jackson, 2009; Nussbaum, 2000, 2003). As evidence suggests, competition, inequality, and acceleration of the pace of life—essential components of the idea of a good life based on material consumption—in the long run lead to dissatisfaction (Binswanger, 2006; Easterlin *et al.*, 2010).

A promising path is offered by a widespread renaissance of more relational notions of well-being embodied in various initiatives, social movements, and social groups also in developed countries (see for example the Convivialist Manifesto: http://dialoguesenhumanite.org/sites/dialoguesenhumanite.org/files/meetuppage/103/convivialist-manifesto.pdf; the European Degrowth movement (D'Alisa *et al.*, 2014); or the Transition Town movement (Hopkins, 2008). In Latin America, the promotion of the old concept of "Buen Vivir" also embodies collective deliberations on the conditions of a good life for all, including the rights of nature and ecosystems to flourish. Increasing evidence also supports the conclusion that significant relationships with nonhuman nature are constitutive of a good life for many people both in developed and developing countries (Arias-Arévalo *et al.*, 2018; Chan *et al.*, 2016; Kohler *et al.*, 2018; Muraca, 2016). The use of concepts such as 'relational values' help articulate a more adequate language for why people are willing to invest time and attention to the care of ecosystems (Chan *et al.*, 2016; Muraca, 2016; also see chapter 1).

The notion of a good life that most Indigenous Peoples share is deeply relational: the relation to the land with all its interconnected human and nonhuman inhabitants constitutes their collective self-understanding as community. Livelihoods sovereignty is an essential condition to keep this bond. In Ecuador, the rights of Mother Earth (Pachamama) to preserve its condition of regeneration (a different language for biodiversity and ecosystem services) are considered as inseparable from the conditions for a good life of the people and are protected by the Constitution. The Bolivian Constitution includes the consideration of diversity not only ecologically, but also culturally, affirming the rights of the different and diverse indigenous communities in the conception of a plurinational State. These contributions of nature to notions of a good life may be under threat as access to nature—or key components of nature—are lost (Chan & Satterfield, 2016; Garibaldi & Turner, 2004; Kohler *et al.*, 2018; Louv, 2008; Miller, 2005; Nabhan & St Antoine, 1993).

Possible points of action

Governments and other institutions are responsible for enabling subjective, objective, and intersubjective conditions for a good life. Successful policies would generally target the different drivers that affect the desirability and burden of alternative ways of being: socioeconomic (such as competition-driven investment in innovations and the need for new market opportunities), structural (dominant understandings that equate economic growth with well-being), and socio-psychological and cultural (including the social relations in which humans are embedded) (Røpke, 1999).

Promoting alternative conceptions of a good life does not require paternalistic interventions: if the material, social, and personal conditions for a good life are sustained in ways that do not require a high material and energy flow, individuals have the freedom to choose alternative modes of living without significant impairing their quality of life. In this case, sufficiency would not only be an individual choice of voluntary simplicity, but also the legitimate entitlement to a sufficient lifestyle, i.e., the right to have less, to have a slower pace of life, to escape the escalating competition for success and enhancement ('hedonic treadmill'; Binswanger, 2006), without suffering a significant lack in the conditions for a meaningful and dignified life (Winterfeld, 2007). For example, if access to essential services (such as communicating with one's physician or buying a bus ticket) requires specific up-to-date technology, choosing not to use them heavily impacts access to health and mobility. Institutional framing can make the choice of a sufficient and low-impact lifestyle achievable for a large majority of the population, by eliminating burdens or negative incentives.

Improving affordable, spatially inclusive and comprehensive public transport infrastructure would expand fundamental entitlements to mobility, enabling people to embody more collective notions of a good life without substantial compromise to security, comfort and efficiency.

Regulation of planned obsolescence for technological products would shift innovation towards ecological design and long-lasting, modular products, thus increasing the freedom of choice of consumers while improving the social and environmental conditions under which electronic devices are produced. It would also in the long run affect the cultural understanding of innovation and originality while significantly reducing environmental impacts (e.g., through rare earths mining).

Expectations of increasing speed in social interactions often correlate with increasing impact on nature due to associated infrastructural needs. Policies and programs that counteract acceleration tendencies and promote spaces for solidarity, care, creativity, and democratic participation might enable the achievement of essential features of a good life and expand freedoms. Technological innovation can significantly contribute to reframing the conditions of acceptability of social behaviours as well (e.g., the "do not disturb while driving" feature on recent smartphones might reduce the expectation of immediate response to messages).

Such interventions would foster a shift—in the long run—from the role of consumers to that of users (Lebel & Lorek, 2008) without significantly impairing the capabilities of people to achieve valuable doings and beings. Supporting alternative modes of production based on peer-to-peer processes would increase local resilience, make technologies accessible and decentralized, and promote the autonomy and self-determination of local communities (Kostakis & Bauwens, 2014).

Ultimately, a fundamental condition for a good life is the possibility of deliberation and negotiation within a society. Participatory parity (Fraser, 2007) is key. This entails different social groups being able to speak in their own terms and language about their understanding of a good life and enabled to participate in the framing of its conditions (Fraser, 2007).

5.4.1.2 Aggregate consumption (a function of population, per capita consumption and waste)

Beyond improved efficiencies and enhanced production, all pathways to reducing biodiversity loss entail reducing or reversing the growth of aggregate consumption, as a function of population size and per capita consumption and waste. Per capita consumption tends to rise as income rises, putting further pressure on biodiversity. Upward trends in population growth have and will lead to further biodiversity loss and increasing numbers of threatened species. The need for transformative changes in consumption patterns is particularly pertinent for wealthier nations and people.

Background

Across 114 nations, the number of threatened species in the average nation is expected to increase by 14% by 2050 (McKee *et al.*, 2004); and increased efficiency in food production is unlikely to compensate sufficiently for the negative impact of human population growth and increasing per capita consumption on biodiversity (Crist *et al.*, 2017). Expected changes in population and income between 2010 and 2050 suggest that the environmental effects of the food system, as one example, could increase by 50–90% without substantial technological changes and dedicated mitigation (Springmann *et al.*, 2018a). Globally, decreases in consumption are thus critical, recognizing that there are significant inequalities within and between countries in consumption related to food, energy, water, and other natural resources (O'Brien & Leichenko, 2010).

Aggregate consumption is a function of population size *and* per capita consumption. An example of these effects at a fine scale is that households with fewer members tend to have higher per capita consumption, with consequences for biodiversity, especially in biodiversity hotspots (Liu *et al.*, 2003). Cities are more efficient resource-users per capita than sparsely populated areas due to economies of scale, in particular with infrastructure (EEA, 2015). On the other hand, urbanization has also been found to increase consumption at the household scale. Specifically, the ecological footprints (an index of major consumption categories at the household level; see chapters 2 and 3) of nineteen coastal cities across the Mediterranean reveals that per capita footprints are larger on average than parallel rural populations. The main drivers were found to be food consumption, transportation and consumption of manufactured goods (Baabou *et al.*, 2017). In general, the co-benefits of urban systems as both source and solution of environmental effects are not well studied.

Evidence

Aggregate consumption (the product of population size and per capita consumption and waste) is undisputably a key driver of environmental degradation (Dietz *et al.*, 2007; Ehrlich & Pringle, 2008; Rosa *et al.*, 2004). As one prime example, food consumption drives the agricultural sector (which covers 38% of Earth's surface), and is as a primary source of environmental degradation and GHG emissions (both drivers of biodiversity loss). Seventy-five per cent of that agricultural land is used for livestock production (Foley *et al.*, 2011). In particular, demand for animal source foods has more than tripled over the past 50 years due to population growth and dietary change (Delgado, 2003; Thornton, 2010). Livestock production (grazing and feedstock) is the single largest driver of habitat loss, a pattern increasing in developing tropical countries where the majority of biological diversity resides. The projected land base required by 2050 to support livestock production in several megadiverse countries exceeds 30–50% of their current agricultural areas (Machovina *et al.*, 2015). Some reduction in biodiversity loss can be offset through technological gains such as yield gains in agriculture due to intensification (Wirsenius *et al.*, 2010), but these do not yet keep pace with simultaneous growth in population and income (West *et al.*, 2014).

Changes in consumption patterns are among the most prominent elements in storylines used in scenarios that lead to achieving SDGs, including all three elements (population size, per capita consumption, and waste). The core global studies (Roads to Rio+20, Pathways to the 1.5ºC target, and Bending the Curve—5.3.1.2) all assumed relatively low stabilized global population sizes and various scenarios of reduced overconsumption and waste. More specifically, Stehfest *et al.* (2009) showed that four scenarios of dietary variants, all involving reduced meat consumption yielded diminished land-use change (and associated, non-modelled, benefits for BES) and reduced emissions and energy demand. Meanwhile, energy scenarios suggest that focusing on the energy use of sectors, not people, would lead to substantial reduction in energy demand (see McCollum *et al.*, 2012's energy efficient pathway).

These patterns in scenarios contain some important complexities but lack others. One key missing nuance in large-scale scenarios is the minimal representation of rebound effects (Jevons paradox), by which consumption often tends to increase in response to gains in efficiency in production or resource intensity, erasing some or all of the gains (e.g., LED lighting may be more efficient but enable much more lighting in total; more abundant energy may encourage greater consumption) (Alcott, 2005). Accounting for these rebound effects would make the case even clearer that ***increased production and efficiency are not sufficient, without also addressing consumption itself***. In terms of food consumption, modelled patterns often somewhat underrepresent variation within agricultural systems, and the important role dairy and foods of animal original play in childhood, maternal (during pregnancy) and elderly nutrition (FAO, 2016)(). For instance, few scenarios account for feedbacks between changing availability of protein affects local hunting or fishing (Brashares *et al.*, 2004), where wild-based and so small-scale economies, such as bushmeat provisioning, have also been identified as an important driver of biodiversity loss (Fa *et al.*, 2005; Nasi *et al.*, 2008). Terrestrial wildlife, especially ungulates, are a primary source of meat for millions globally. Wild meats are however an important source of childhood nutrition, without which an estimated 29% increase in children suffering from anemia would occur, leading to health, cognitive and physical deficits in poor households (Golden *et al.*, 2011). Virtually all models do include some level of meat and fish derived proteins. Furthermore, all models related to the role of dietary changes recognize that dietary changes, such as lowering animal protein consumption do not apply to undernourished and vulnerable populations. The general point is that lowering consumption of animal protein is important; and that variation aside, even the lowest impact of animal protein production typically exceed the impact of plant-based options (Clark & Tilman, 2017; Poore & Nemecek, 2018).

Waste is equally key. A large amount of food, including animal products, is wasted worldwide, e.g., roughly 30% in the U.S. when accounting for production through household waste (Nellemann, 2009). Wasting 1 kg of feedlot-raised boneless beef is estimated to have ~24 times the effect on available calories as wasting 1 kg of wheat (~98,000 kcal versus ~4000 kcal) due to the inefficiencies of caloric and protein conversion from plant to animal biomass (West *et al.*, 2014). Waste varies greatly between countries: food loss in India for vegetables and pork is <3 kcal per person day–1, versus ~290 kcal per person day–1 for beef in the United States. Approximately 7 to 8 times more land is required to support this waste in the United States than in India (Machovina *et al.*, 2015). Overall, because waste in the production cycle is so variable, even for the same food types and classes, producer-level monitoring and mitigation will be key to achieving more sustainable pathways (Poore & Nemecek, 2018).

Overproduction (when not discarded to prop up prices) and associated marketing can also drive consumption: if subsidies or other forces yield an oversupply of a commodity or good, this will lower prices, and consumption of those goods and their embodied resources will tend to rise. Producers can boost these effects strongly through advertising, which can yield self-reinforcing dynamics in consumer culture (Berger, 2015; Isenberg, 2017; Philibert, 1989).

Possible points of action

It is estimated that countering these driving forces would require incentives for increases in the efficiency of resource use of about 2% per year (Dietz *et al.*, 2007), and no single measure or action will be sufficient. Intensification will offset some effects of consumption in the agricultural sector, but much gain would accrue via reduction in meat consumption through demand reduction and dietary shifts (Foley *et al.*, 2011). As with all efficiencies, some rebound effects are to be expected and addressed (e.g., increased demand that follows initial gain through efficiency) (Alcott *et al.*, 2012).

An estimated 1.3 to 3.6 billion fewer people could be fed if diets shifted to lessen reliance on animal products, particularly resource-demanding ones (while maintaining the relative contribution of grazing systems) (Davis & D'Odorico, 2015). Some analyses suggest that targeting Western high-income and middle-income countries would yield the largest potential gain and focus for the environmental (and health) benefits of dietary changes at a per capita level (Springmann *et al.*, 2014). Improvements in consumption patterns can likely be achieved by reducing subsidies for animal-based products, increasing those for plant-based foods, and replacing ecologically inefficient ruminants (e.g., cattle, goats, sheep) (Machovina *et al.*, 2015). Research and development of plant-based meat substitutes is also a growing phenomena and potential solution (Elzerman *et al.*, 2013; see also Poore & Nemecek, 2018; Springmann *et al.*, 2014, 2018b).

Significant targeting of waste is also an important policy target; well tested approaches include regulations for Extended Producer Responsibility whereby producers manage the waste generated by their products (OECD, 2016).

Given the central role of advertising and marketing in boosting production, policies might seek to rein in the reach of advertising, particularly to children and for resource-intensive products. Lastly, broader changes in consumption could be triggered by promoting alternative models of economic growth (e.g., as proposed by the World Business Council for Sustainable Development, WBCSD, 2010), which may also offer higher likelihood of achieving SDGs 2, 6, 15.

5.4.1.3 Latent values of responsibility and social norms for sustainability

Sustainable trajectories are greatly enabled by context-specific policies and social initiatives that foster social norms and facilitate sustainable behaviours. An important step toward this goal would be to unleash latent capabilities and relational values of responsibility (including virtues and principles; 5.4.1.1). Such values may often be strongly held in relevant populations, but not manifest in large-scale action due to a lack of enabling conditions, including infrastructure and institutional arrangements. Because communities, the values they hold, and barriers to enacting values are all diverse and multifaceted, social norm-shifts and widespread action are most likely to stem from locally tailored programs, policies and investments.

Evidence

There is strong evidence that many populations already express values consistent with sustainability, such as pro-environmental values (e.g., Dunlap & York, 2008) and relational values (Klain *et al.*, 2017). These values manifest differently in different places (Chan *et al.*, 2016). For example, Haidt & Graham (2007) document a striking difference in moral foundations between progressive and conservative voters in the USA, and the World Values Survey reveals two major axes of difference (traditional vs. secular-relational values and survival vs. self-expression values) (World Values Survey, 2016). In both of these frameworks, values on either end of these spectra could support sustainability.

Ample evidence supports that the expression of such values is currently impeded by insufficient infrastructure and social structures (Shove, 2010). This 'social practice' strand of research demonstrates the need for explanations of collective action (e.g., issues involving greenhouse gas emissions) to go beyond the aggregate of individual people operating independently. This research suggests that the focus on individual attitudes, behaviours, and personal choice needs to be expanded to include systemic considerations, such as the role that governments play in "structuring options and possibilities" (Shove, 2010). As one important possibility, sometimes norms can be promoted in new contexts by foregrounding existing widely held norms and values, and their applicability to the issue at hand via a process called 'normative reframing' (Raymond *et al.*, 2013). Thus, notions of justice or fairness can be applied in new environmental contexts, either through normative reframing or even the creation of new norms in 'normative innovation' (Raymond *et al.*, 2013).

Extensive work on barriers to pro-environmental behaviour, which originates from an individual-focused paradigm, also often discusses two main realms of barriers: personal and collective. This work provides evidence that individual-level factors (e.g., disposition) play a role in behaviour, and it also confirms the importance of factors external to the individual (Darnton & Horne, 2013; Kollmuss & Agyeman, 2002). In short, though individual motivation is important, the problem is sometimes or often not that individuals lack motivation for action (e.g., on climate change), but rather that current infrastructure, habits, and norms are outdated and insufficient to express values already present. An example from the United States relates to personal transportation, many people report wanting a lower carbon alternative to personal vehicle travel, but their communities are designed in such a way that make other options prohibitively inconvenient and/or unappealing (Biggar & Ardoin, 2017b, 2017a; Shove & Walker, 2010).

Related to the point above, but stemming from a parallel literature, extensive behavioural economics and psychological research suggests that human decisions are heavily impacted by context and structures. There is strong evidence from a range of studies and a larger body of social sciences literature that replacement or evolution of infrastructure and social structures could nudge change in individual behaviour and also contribute to the formation of pro-sustainability habits and norms (Pallak *et al.*, 1980; Thaler & Sunstein, 2008). A fundamental idea underlying this philosophy, which has been called "liberal paternalism" because it allows free choice (liberal) but guides people (paternalistic), is that people often want to act differently than they do, and would often appreciate a "nudge" to help them act in accordance with their deeper values. One specific example would be that people wanting to purchase sustainable seafood have benefited from a green-yellow-red signaling system, especially when those signals are displayed beside the products in stores and restaurants. A more general example would be that people wanting to donate more to charity generally give more with automatic payment plans.

Additional evidence suggests that despite the responsiveness of human behaviour to existing contexts, moral belief and conviction already do transcend purely selfish action and/or more mechanical responses (e.g., of the type described by moral psychology or behavioural economics) (Damon & Colby, 2015). Learning can help people develop these responses based on morals and conviction, especially when that learning employs dialogue, reflection, reasoned argumentation, and deliberation (all of which practices are increasingly recommended by education scholars; see 5.4.1.8). A cornerstone of much moral philosophy is the idea that people can engage with complex situations and, through conscious deliberation and moral judgement, change behaviours and lifestyles. Acknowledging the aforementioned substantial impact of sometimes minor situational and contextual variables, it is helpful to also consider research into human moral choice, and how morality and moral decisions come about. Much research in this realm highlights the importance of intentional effort, deliberative discussion and thought (including in education), not as an alternative to 'nudge' approaches but as a complement (John *et al.*, 2009; Reed *et al.*, 2010).

Fifth, the burgeoning science of norms offers important insight into how to change behaviour. The science of norms considers the interplay of proximate contextual factors (e.g., what people around us are doing) and more deeply rooted social, collective understandings of "how things should be." Norm-based interventions are some of the most prevalent and effective means of changing behaviour (Miller & Prentice, 2016). As one example, household use of electricity decreases following messages about neighbors who use less electricity (the addition of a message conveying social approval/disapproval further strengthens the change; Schultz *et al.*, 2007). Norms interventions, particularly related to environmental issues, are less common in developing countries; an example from the health field is that decreases in female genital mutilation followed interventions that attended to social norms along with other aspects of local context (Cislaghi & Heise, 2018). Research on the dynamics of norms (i.e., how norms change) focuses on the need to change expectations, both about what others will do and what others think people should do (Wegs *et al.*, 2016). Legislation can affect these changes under specific conditions (e.g., when policies are not too far from aligning with existing social norms) (Bicchieri & Mercier, 2014). For most cases, however, interpersonal interaction is central to changing norms. Discussion can encourage prosocial behaviour by signalling and emphasizing desirable behaviours and norms (Balliet, 2009; Sally, 1995). Discussions also help people understand why others feel as they do and allow people to grapple with disagreement. In some situations, for instance those in which people need to be convinced, argumentation may be required (Bicchieri & Mercier, 2014). Work from a variety of fields confirms the importance of interpersonal interaction and discussion; one study, for instance, found time spent with neighbors to be strongly correlated to "environmental lifestyle" and "willingness to sacrifice", emphasizing the importance of non-kin social relationships and interactions (Macias & Williams, 2014).

For IPLCs, values of all kinds (e.g., instrumental, intrinsic, relational) are deeply intertwined with cultural and environmental contexts, and value systems are often represented in and reinforced by language. The loss of language may be associated with value deterioration or change. Many (if not all) languages codify values related to the ability to coexist with surrounding environments for hundreds or thousands of years (Davis, 2009; Maffi, 2001). These sustainability-related values may be particularly common in Indigenous and other long-standing local communities, with their strong traditional beliefs, laws, customs, culture, and affections towards nature (e.g., sacred trees, sacred animals, totems) (e.g., McGregor, 1996; Turner, 2005). As such, the loss of languages is potentially a major problem for value diversity and authenticity. In many regions, community values that support sustainable trajectories using indigenous knowledge are at risk of extinction, which results in the loss of biodiversity (Unasho, 2013). Loh and Harmon (2014) note that one in four of the world's 7000 languages are at current threat of extinction, confirming a simultaneous decline in linguistic diversity and biodiversity – approximately 30% since 1970. Extinction statistics tell the story: 21% of all mammals, 13% of birds, 15% of reptiles, 30% of amphibians and 400 languages have gone extinct (Loh & Harmon, 2014). In this sense, the value of the knowledge-practice-belief complex of Indigenous Peoples relating to conservation of biodiversity are central to the sustainable management of ecosystems and biodiversity.

Possible points of action

A particular challenge faces people participating in global supply chains (e.g., through their purchasing of goods and services), because although there might be broad and strong agreement with the notion that we humans have a responsibility to account for our impacts on the environment (Klain *et al.*, 2017), there are a dearth of options for people to do so easily, enjoyably, and affordably (Chan *et al.*, 2017b). That is, the primary option available to consumers is the purchase of certified products (e.g., Marine Stewardship Council seafood, forest-stewardship council wood products, organic food), but these are inevitably costly, limited, and complex (few consumers can keep track of and come to trust more than a few of the plethora of competing labels). Because the costliness stems partly from inefficiencies in these niche supply chains, there is potential to enable widespread action in accordance with values of environmental responsibility via credible non-tradeable offsets that enable organizations and individuals to mitigate their impacts on nature (Chan *et al.*, 2017a). A legitimate and trusted system of such offsets does not yet exist, but there are important developments and novel efforts (e.g., the Natural Capital Project's Offset Portfolio Analyzer & Locator, Forest Trends' Business & Biodiversity Offsets Programme, CoSphere).

Offsets have a potentially important role to play because they could enable people and organizations to enact values of environmental responsibility that are currently suppressed by disabling conditions, but which could potentially yield new social norms. However, to achieve that, it will be crucial that offsets avoid the problems and associated negative reputation that has plagued carbon offsetting, such that offsets convey the real and socially legitimate mitigation of diverse impacts on nature and its contributions to people (Chan *et al.*, 2017a).

5.4.1.4 Inequalities

Inequality often reflects excessive use of resources or power by one or more sectors of society at the expense of others. As societies develop and aim to 'catch up' in economic growth, inequality often emerges through control and appropriation of unequal shares of finite resources with implications for both creating unjust social conditions and loss of nature and its contributions. Therefore, addressing societal inequities is not only important for its own sake and for moral reasons, but as leverage to facilitate achievement of biodiversity goals.

Background

The world is currently experiencing increasing levels of inequality in many sectors of society, including between, within countries and across countries (Stiglitz, 2013). Although assessments of inequality often focus on income, there are many dimensions of societal inequalities such as distributive, recognition, procedural and contextual inequities (Leach *et al.*, 2018). Distributive equity refers to the distribution of costs and benefits, and questions of who gains and who loses. This is very applicable for example to the climate discussion where questions are raised about who bears the responsibility for or burdens of climate impacts (Collins *et al.*, 2016; Dennig *et al.*, 2015). This may also include discussion about unequal access to health across and within countries (Costello & White, 2001; Joshi *et al.*, 2008) or inequality in access to energy (Lawrence *et al.*, 2013; Pachauri *et al.*, 2013) and inequalities in income distribution (Alvaredo *et al.*, 2018; Piketty & Saez, 2014; Ravallion, 2014). Procedural equity refers to access and participation in decision-making processes and applies to discussion about gender inequality and representation in governance structures, education, and other spheres of society (McKinney & Fulkerson, 2015). Recognition equity refers to accounting for stakeholders' knowledge, norms and values, and this is the main driving force behind IPBES and other organisations' calls for including indigenous and local knowledges, expanding the values base and opening up to multiple forms of evidence (Díaz *et al.*, 2015; Nagendra, 2018; Pascual *et al.*, 2017a; Tengö *et al.*, 2017). Finally, contextual equity refers to deep rooted social conditions, such as gender, social structure, discrimination and historical legacies that help to explain why inequality is perpetuated and reproduced over time (Martin *et al.*, 2016; McDermott *et al.*, 2013). All these different dimensions of inequities and inequalities can apply variously to gender equity, equity between specific groups, or between vulnerable groups and between different segments of society (Bock, 2015; Daw *et al.*, 2015; Keane *et al.*, 2016; Terry, 2009).

Evidence

Global inequalities, between and within countries, include inequities in income and wealth, inequities in access to resources and other benefits, as well as inequities in who bears the brunt of global change.

Globally, income inequality is increasing while biodiversity loss continues apace (Butchart *et al.*, 2010; Dabla-Norris *et al.*, 2015). Although the mechanisms of how income inequality affects biodiversity loss are not yet articulated comprehensively, there is some indication that income inequality is positively correlated with biodiversity loss. Inequality has been associated with an increasing number of social and environmental problems (Islam, 2015; Jorgenson *et al.*, 2017; Wilkinson & Pickett, 2010). Several studies suggest some initial hypotheses for the observed negative coarse-scale correlations between biodiversity and inequality (Holland *et al.*, 2009; Mikkelson *et al.*, 2007; Mikkelson, 2013). Here income inequality, measured using the Gini index, is correlated positively with threatened species, suggesting that inequality may exacerbate biodiversity loss. It also appears that a psychological acceptance of inequality (as measured by the social domination orientation) is negatively correlated with a variety of environmental actions and behaviours, and that this negative relationship is stronger in nations characterized by societal inequality (Milfont *et al.*, 2017).

More broadly however, inequality is seen as resulting from broader structural issues. In this way, unequal access to incomes, resources, consumption and other forms of inequality are symptoms of larger structural configurations related to power asymmetries and political influence (Cushing *et al.*, 2015; Pieterse, 2002). Some of explanations of this assertion include the existence of phenomenon such as 'ecologically unequal exchange', which is a structural mechanism allowing for more developed countries to partially externalize their consumption-based environmental impacts to lesser developed countries (see chapter 2.1; Jorgenson *et al.*, 2009). While there are some nuances to this suggestion (Moran *et al.*, 2013), there is evidence showing unequal consumption patterns between developed and developing countries (Wilting *et al.*, 2017), and 'trade of biodiversity' from developing countries to developed countries (Lenzen *et al.*, 2012). For example, there is evidence suggesting inequalities in access to health (Costello & White, 2001; Joshi *et al.*, 2008), energy access (Lawrence *et al.*, 2013; Pachauri *et al.*, 2013), climate change and other environmental burdens and responsibility (Collins *et al.*, 2016; Dennig *et al.*, 2015), income distribution (Alvaredo *et al.*, 2018; Piketty & Saez, 2014; Ravallion, 2014), between countries, individuals, genders and other socially differentiable segments of society (Aguiar & Bils, 2015; Bebbington, 2013; Chaudhary *et al.*, 2018; Lau *et al.*, 2018; Piketty & Saez, 2014).

Possible points of action

There are increasing numbers of suggestions and solutions for addressing inequality in society. For example, the concept of 'common but differentiated responsibility' has taken root in multinational agreements, is now a principle within the United Nations Framework Convention on Climate Change (UNFCCC). It acknowledges the different capabilities and differing responsibilities of individual countries in addressing climate change (Rajamani, 2000; Stone, 2004). Given different countries' historically different responsibilities and benefits in use of and access to resources, this principle could be applied more broadly to other spheres of biodiversity management.

Within nations, there are other solutions to inequality such as United Nations Development Programme's Inclusive Growth (UNDP, 2017). Others still advocate for universal provision of services including universal health care, universal education, basic social services, and regressive taxation. One of these universal provisions that is gaining traction is universal basic income (Lowrey, 2018).

5.4.1.5 Human rights, conservation and Indigenous Peoples

Sustainable trajectories that achieve biodiversity and Sustainable Development Goals need to maintain or enhance ecosystem services on which livelihoods depend as concerns Indigenous Peoples and land-based (and often poor) people living in or adjacent to all classes of protected areas. Achieving large-scale engagement of Indigenous Peoples and Local Communities (IPLCs) in protected areas governance entails (a) recognition of and compensation for historical wrongs and transgressions of rights in conservation contexts; (b) IPLC-led planning, decision-making and consent (which is significant and robust); and (c) connection of local efforts with larger connected landscapes/seascapes to enable the continued benign use of ecosystem services in broader landscapes and seascapes. Human rights are linked to but not inclusive of the rights of nature across these considerations.

Evidence

Some conservation efforts have led to Indigenous Peoples and Local Communities being displaced from traditional territories and deprived of access to resources essential to their livelihood (Agrawal & Redford, 2009; West & Brockington, 2006; see also chapters 3 and 6). This was true across many colonial administrations wherein reserves were often created as hunting reserves or settler communities (Griffiths & Robin, 1997; Neumann, 1998). These reserves impinged upon forest and land-dependent communities (Duffy *et al.*, 2016). There are also reports of similar patterns of restrictions and conflicts with contemporary pastoralists (Holmern *et al.*, 2007) and swidden agriculturalists (Harper, 2002). As conservation efforts have escalated in the contemporary period, this pattern has continued, with some exceptions (Davies *et al.*, 2013). International organizations in the last two decades have come to recognize that the involvement of local people is an essential prerequisite of any attempt to achieve better conservation and natural resource management (Kakabadse, 1993; McNeely, 1995). However, there have been ongoing reports of violent and militarized conservation actions including shoot-to-kill orders issued for poachers (Lunstrum, 2014). Recent examples come from the USA, Cambodia and southern African countries (Ramutsindela, 2016), including cases where relocation has failed and violence has escalated as a partial consequence (Hübschle, 2016).

In many countries, both in Global North and South, the processes of allocating land rights are still a work in progress. People with legitimate and historical rights to territorial use and jurisdiction have often had difficulty gaining recognition of these rights in processes of land allocation. Misidentifying people as stakeholders rather than rights-holders has often enabled human rights abuses by lessening the obligations of duty bearers (those responsible to protect and enable viable conditions such that human rights are ensured) (Alcorn & Royo, 2007). Failure to recognize the presence and role of historical wrongs has often deepened or exacerbated tensions about or the creation of just forms of conservation (Chan & Satterfield, 2013). This has included histories of displacement often linked to 'fortress conservation' (Büscher, 2016), forced relocation and loss of livelihoods (Brockington & Igoe, 2006), colonial legacies, transgression of treaty rights, and failed restitution for historical losses (Colchester, 2004). The designation of protected areas without meaningful involvement of those most affected (Hockings *et al.*, 2006) has been widespread, so much so that some populations are not aware that they are living within a designated protected area and that conditions of use have thus changed (Sundberg, 2006).

Pressure from national and international organizations related to human rights and to conservation has placed pressure on policymakers in countries with rich biodiversity, sometimes with undesirable effects. Even attempts to achieve conservation through community-based management have not always fully addressed the fundamental rights of local people, even in better designed systems such as those known as community-based conservation (Berkes, 2004; Campbell & Vainio-Mattila, 2003). Cernea and Soltau (2006) have documented cases where conservation has deepened poverty and food insecurity as a result of restrictions imposed on resource use, most acutely in cases of forced relocation or involuntary resettlements. Sachs *et al.* (2009) have documented cases where a disproportionate conservation burden has been placed on already poor and marginal communities thereby increasing transitions into more severe forms of poverty.

The loss or degradation of social status has also accompanied conservation activities, often due to the relocation of peoples to hostile host communities (Martin, 2003) or the stigmatizion of some peoples because their land-use practices are deemed destructive by conservation agents (Bocarejo & Ojeda, 2016). Compensation for losses directly attributable to conservation (e.g., due to loss of lands, or loss of resources or income as the result of human-wildlife conflicts) have often been insufficient (Cernea & Schmidt-Soltau, 2006) or have failed to recognize losses most meaningful to impacted communities (Witter & Satterfield, 2014). Communities have often waited far too long in far too compromising circumstances for promised relocation packages when being moved to improve the status of parks and protected areas (Hübschle, 2016). Lastly, when conservation efforts have been poorly executed due to problems of governance, corruption, or in areas with histories of war and armed conflict, violent and militarized conservation has often ensued and harmed human and nonhuman communities (Smith *et al.*, 2015).

Given the vast lands over which IPLCs exercise traditional rights, recognizing land rights and partnering with Indigenous Peoples could greatly benefit conservation efforts (Garnett *et al.*, 2018). According to Garnett et al. (2018), Indigenous Peoples either traditionally own, manage, use or occupy at least a quarter of the global land area, constituting approximately 40% of land that is currently protected or ecologically intact. IPLCs frequently have a rich set of relational values regarding nature and their interactions with it, and some of these are consistent with conservation, although often not as it has been practiced historically (through exclusion) (Chan *et al.*, 2016; Pascual *et al.*, 2017a). Involving IPLCs justly and appropriately in conservation could help them manage other pressures, such as resource extraction, in a way that meets both local and global needs.

Possible points of action

Recent innovation among conservation organizations has seen investments in engaging local communities in exploring future scenarios to achieve conservation and development, thus involving communities at an early stage of conservation and sustainable development programs (Boedhihartono, 2017; Clarke, 1990; Curran *et al.*, 2009; chapter 6).

Needs remain, however, for measures to directly and indirectly address enduring negative consequences of conservation for local and Indigenous Peoples. Improved forms of community-based conservation might ensure that the rights of nature do not supersede human rights (Hockings *et al.*, 2006). For instance, conservancies established in southern Africa have enabled local decision-making to be sustained across decades (Boudreaux & Nelson, 2011; Tallis *et al.*, 2008). Many countries are beginning to return land and forests to local communities and indigenous groups. Notable successes have been achieved in the last decade, and wider adoption of such programs for forests and biodiversity conservation could address the issues raised here (Adams, 2001; Boedhihartono, 2017; Sayer *et al.*, 2017).

Adaptive management (5.4.2.4) is viable when people are well integrated into the social-ecological system being conserved, and distribution of economic and social benefits contribute to improve the lives of IPLCs (Berkes, 2004; Infield & Namara, 2001). There are examples of successful action drawing on traditional ecological knowledge and practice, which have been combined with western concepts of conservation to produce multi-disciplinary management outcomes (Gadgil *et al.*, 2000; Huntington, 2000).

Enabling local definitions and targets for nature's contributions to people is also key, especially those that go beyond market measures and enhance well-being (Sandifer *et al.*, 2015). Working with locally-defined compensation and resettlement planning can help improve or restore livelihoods and development opportunities (Bennett *et al.*, 2017; Vanclay, 2017). Compensation for crop losses can also improve support for conservation initiatives and is being widely used, though challenges remain (Karanth & Kudalkar, 2017; Nyhus *et al.*, 2005).

In the rare instances where relocation appears necessary, fairness might dictate the suspension of processes if they cannot be realized well and fairly in an appropriate time frame (Hübschle, 2016). Strong stances against militarized and armed conservation will help restore deeply eroded people-park relations and 'de-criminalize' livelihoods (Duffy *et al.*, 2015).

Schemes such as payments for ecosystem services (PES) are most likely to succeed in conditions where livelihoods are already relatively secure, and payments are supplemental and not a replacement for income or food security (Pascual *et al.*, 2014).

The social complexities of landscapes can be integrated when designing compensation schemes for conservation at community levels (Wunder *et al.*, 2008). It is inevitable that trade-offs will occur between biodiversity and ecosystem service goals (chapter 2.3), but these trade-offs can be made fairly if addressed explicitly and democratically (Borrini-Feyerabend *et al.*, 2013).

Last, Indigenous Peoples and Local Communities can be integrated, along with other actors, in landscape-level governance through the recognition of both ancient practices and innovative mechanisms. The relationship between human activities and the environment also creates unique ecological, socioeconomic, and cultural patterns, and governs the distribution and abundance of local species, which are often described as cultural landscapes in western society (Farina, 2000; Plieninger & Bieling, 2012). Exemplar practices exist in other parts of the world that represent harmonious interactions between humans and the nature such as Satoyama and Satoumi of Japan, Pekarangan (homegarden) of Indonesia, Chitemene of Zambia, Malawi, and Mozambique, and are now collectively described as 'Social-Ecological Production Landscapes and Seascapes (SEPLS)' (Gu & Subramanian, 2014; Takeuchi, 2010). Similarly, the framework and designation of the Globally Important Agricultural Heritage Systems (GIAHS) by FAO since 2002 and the International Partnership for the Satoyama Initiative (IPSI) since 2010 (Box 3.1, chapter 3 for more detail) aims to identify and improve recognition about remarkable land-use systems and landscapes that have long provided various ecosystem services while contributing to biodiversity conservation and maintenance of Indigenous and local knowledge (FAO, 2010; Lu & Li, 2006; Nahuelhual *et al.*, 2014).

5.4.1.6 Telecouplings

Achieving global sustainability goals will likely require a targeted focus on the distant effects of local actions (telecouplings, such as spillover effects). Many existing environmental policy frameworks enable jurisdictions to meet targets by externalizing impacts to other jurisdictions (e.g., national greenhouse gas emissions and water use can and have been reduced in part by importing GHG and water-intensive agricultural commodities rather than producing them). While these allowances may have benefits, global sustainability will require assessing, addressing, and closing these loopholes.

Background

Systems in distant places across the world are increasingly interconnected, both environmentally and socioeconomically. The term telecoupling was created to describe socioeconomic and environmental interactions between multiple coupled systems over distances (Liu *et al.*, 2013). The concept of telecoupling is a logical extension of coupled human and natural systems because it connects distant systems instead of just studying individual systems separately or comparing different systems.

Telecoupling is an umbrella concept that encompasses many distant processes, such as migration, trade, tourism, species invasion, environmental flows, foreign direct investment, and disease spread. It expands beyond distant socioeconomic processes such as globalization by explicitly and systematically including environmental dimensions, and expands beyond distant environmental processes such as teleconnection by explicitly and systematically including socioeconomic dimensions simultaneously. As such, telecoupling emphasizes reciprocal cross-scale and cross-border interactions (e.g., feedbacks). It also helps to better understand interactions among multiple distant processes (Liu *et al.*, 2015a). Many telecouplings have existed since the beginning of human history, but their speed is much faster, their extents much broader, and their impacts much larger than in the past. Furthermore, current telecouplings occur in an entirely new context with many more people and more tightly constrained resources than ever before. Telecoupling can affect biodiversity and nature's contributions to people in distant locations and across local to global scales, with profound implications for the Aichi Biodiversity Targets, Sustainable Development Goals, and the Paris Agreement.

Spillover effects have been largely overlooked. For example, for international trade, the focus has been usually on impacts on trade partners. Several studies have reported spillover effects (also called offsite effects or spatial externalities) (e.g., Halpern *et al.*, 2008; van Noordwijk *et al.*, 2004). Placing spillover effects under the telecoupling framework can facilitate holistic understanding and management of the effects, as it helps to not only uncover the effects, but also connect them with causes and agents as well as flows across all relevant systems.

Evidence

As illustrated in Supplementary Table 5.4.4, many studies have demonstrated impacts of telecouplings on nature and nature's contributions to people. International trade has substantial impacts on ecosystem services and biodiversity in exporting countries (Lenzen *et al.*, 2012). Traditional trade research has focused on socioeconomic interactions between trade partners at the national scale, with some separate studies centered on environmental impacts (e.g., DeFries *et al.*, 2010; Lambin & Meyfroidt, 2011). More recently, studies have also showed that patterns of international investments through tax havens also have a direct impact on biodiversity loss in commodity-producing regions such as the Amazon (Galaz *et al.*, 2018). Such impacts result from land conversion from natural cover such as forests to crops (Brown *et al.*, 2014), or from pollution of water or air. It is clear that importing countries obtain environmental benefits (e.g., land allocation for biodiversity conservation and restoration rather than food production) at the expense of environmental degradation in exporting countries (Galloway *et al.*, 2007; Lenzen *et al.*, 2012; Moran & Kanemoto, 2016). For example, imports of food and other goods often have associated ecological footprints in producing regions (MacDonald *et al.*, 2015).

Spillover effects occur all over the world. These effects can be positive or negative, socioeconomic and/or environmental. They can be more profound than effects within the systems being actively managed. Evidence so far indicates that spillover effects are largely negative, such as degrading distant biodiversity, ecosystems and ecosystem services. In fact, much of the environmental impacts in many nations stem from activities driven by distant demand (e.g., through the production of goods for export; Halpern *et al.*, 2008; also see 5.4.1.2). Spillover effects are so prevalent that even policies intended to enhance regional or national sustainability can be perverse by shifting pressures to other

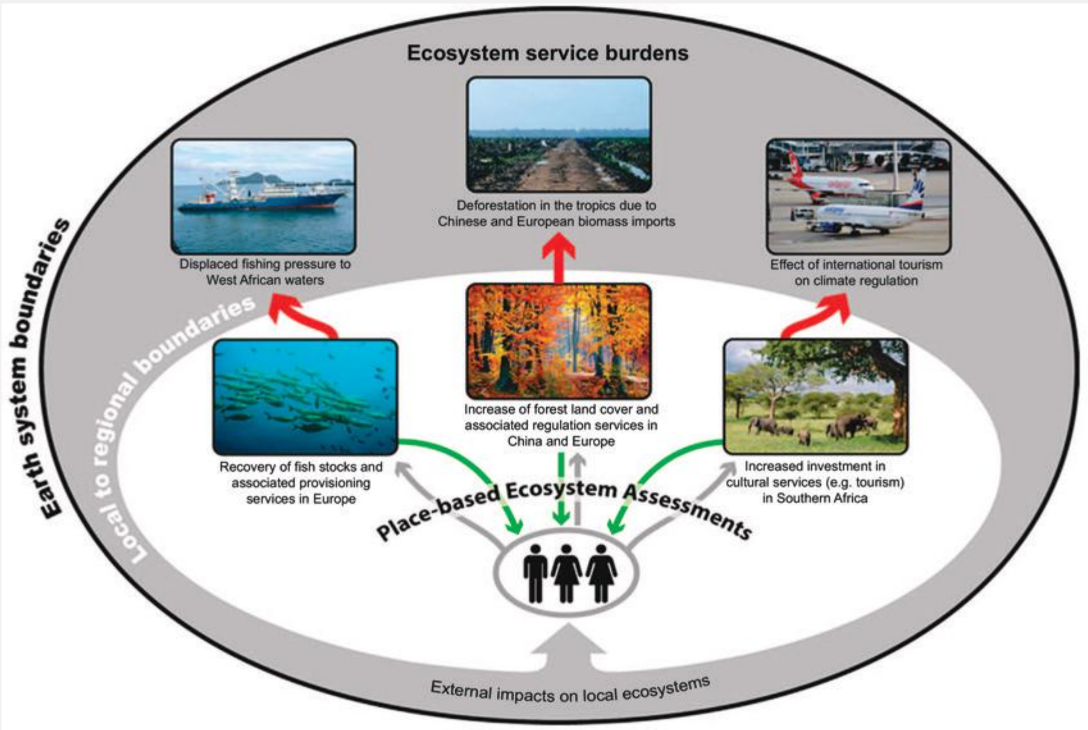

Figure 5 9 **Examples of telecoupling effects, in this case via unintended consequences associated with place-based ecosystem assessments.**

Current ecosystem services assessments focus on the benefits, trade-offs and synergies provided by ecosystem services within a delimited (often jurisdictional) boundary (green arrows) and the impacts that human activities have over such ecosystem services therein (grey arrows). Ecosystem assessments thus tend to overlook off-stage ecosystem service burdens (negative impacts on ecosystem services elsewhere; red arrows) of place-based management decisions and their feedbacks (e.g., due to climate change, bottom arrow re-entering the smaller white ellipse). Figure from Pascual *et al.* (2017b).

places (Pascual *et al.*, 2017b). Those other places may have lower environmental standards (Liu & Diamond, 2005) but richer biodiversity. For example, Sweden reduced rates of logging in Swedish forests, which increased imports from countries with greater forest biodiversity. Sweden also reduced oil use by substituting biofuels derived primarily from Brazilian sugar cane ethanol (Bolwig & Gibbon, 2009).

Even conservation efforts can generate negative spillover effects **(Figure 5.8)**. To conserve Amazonian forests, two supply-chain agreements (i.e., the Soy Moratorium and zero-deforestation beef agreements) have been implemented in the Amazon. Their implementation has substantially reduced deforestation in the Amazon but increased deforestation in the Cerrado (e.g., a 6.6-fold increase in Tocantins State of the Cerrado) (Dou *et al.*, 2018). The US and European Union countries implemented biofuel mandates to reduce their domestic carbon footprints, but these significantly changed land use and increased carbon footprints elsewhere (e.g., Africa, Asia) (Liu *et al.*, 2013).

Possible points of action

International agreements such as the Convention on International Trade in Endangered Species Flora and Fauna (CITES) and Reducing Emissions from Deforestation and Forest Degradation (REDD+) deal with distant interactions (e.g. trade), but could do so more effectively (Liu *et al.*, 2013). For example, telecoupling effects could be systematically integrated into processes of evaluating and revising the Convention and REDD+. Parties who are responsible for telecoupling effects can be identified and held accountable for negative effects (e.g., providing payment or compensation). New agreements may be needed to incorporate telecoupling effects.

Trade policies could be refined to disincentivize trade that entails negative spillover effects. Policies might restrict imports of products whose production entails large environmental damages (perhaps in part because the exporting country has very low environmental protection standards; Liu *et al.*, 2016). For example, the EU's Forest Law Enforcement, Governance and Trade (FLEGT, http://www.euflegt.efi.int/) bans the import of illegally harvested timber as a step to reduce spillover effects, which could be applied to other sectors. Such policies could be designed to raise standards by providing some assistance for nations lacking sufficient environmental governance regimes without punishing nations already suffering from extreme poverty.

Conservation scientists, policymakers and practitioners can also aid global sustainability by considering telecoupling effects in the design and evaluation of conservation policies, paying attention to negative effects outside focal conservation areas. Analyses of outcomes of conservation policies could include spillover effects in addition to the effects on the system in question.

5.4.1.7 Sustainable technology via social innovation and investment

Pathways to a desirable societal future entail a regime change first towards technologies that reduce environmental impacts and then towards those with net-positive impacts. These technological and social innovations must be proactive (not only reactive) and go well beyond the scope of traditional environmental protection policies. A sustainable economy fosters socio-technological systems that maintain, support and apply ecosystem services and biodiversity through different forms of nature-based solutions, including by galvanizing private, but public welfare oriented, investment in nature.

Background

"Technology" is a container term for various approaches to enhance human performance. Scientific assessments of technology neither idealize nor demonize it from an environmental perspective, but consider it as an ambivalent means of achieving particular goals (see, e.g., Davies, 2014; Walker & Shove, 2007).

Whereas technological development and innovation-friendly economies were long combined with a belief in the superiority of technological civilization over nature, insights about the indispensability of ecosystem services and their cost-effectiveness (e.g., Chichilnisky & Heal, 1998) have produced new expectations of technological innovations (see Geels *et al.*, 2015). Even though technological progress cannot be considered a panacea for global sustainability problems, it can contribute to overcoming sustainability challenges under particular circumstances. First, precaution can contribute to minimize or prevent negative or ambivalent outcomes of technologies (see 5.4.2.3; Renn, 2007). Second, shedding past dependencies on unsustainable or less-sustainable technologies contributes to promote innovations and spur new economic opportunities while avoiding pathways that collectively pose non-negligible risks of irreversible effects in ecological systems (Foxon, 2007). Third, ensuring that technological enhancements and resulting efficiency do not stimulate increases in new types of consumption of unsustainable goods or services (Allan *et al.*, 2006; Dimitropoulos, 2007; Herring & Roy, 2007; Lambin & Meyfroidt, 2011).

Industry and businesses are major drivers of ecosystem change. Such positioning highlights the potential for their role in reducing these impacts, which must go beyond marginal improvements (Scheyvens *et al.*, 2016). Earlier sections of this chapter (5.4.1.1, 5.4.1.2) address the needed decoupling of consumption from well-being. Innovations in technology and its usage can play a key role here. Beyond technology, innovation in business models and accounting procedures are central to incorporating environmental externalities into economic decisions. Furthermore, cross-sectoral partnerships and collaborative efforts (e.g., public-private impact investments for public benefit, and multi-stakeholder platforms for commodities that exist for palm oil, sugar, cotton, soy and rubber) facilitate implementation and mainstreaming in business and practice (Dyllick & Hockerts, 2002). Healthy skepticism about the execution of these is merited to guard against greenwashing (see Dauvergne & Lister, 2013), and effective design incorporating monitoring, adaptation and commitment to continued improvement can ensure real on-the-ground impact—but such efforts take time.

The particular role of the private investment sector in supporting sustainable development innovations is subject for debate, both in terms of the needed capital for technological development, and realization of alternative financial mechanisms. Historically, governments fund initiatives that generate public welfare goods, or devise policy and regulation to promote investment or facilitate growth in certain sectors, as has been seen with subsidies (e.g., 5.4.2.1). The scale of transformation and investment required to achieve the Sustainable Development Goals is not possible through government action alone (see SDG 17 on partnerships). Impact investing is a rapidly growing financial mechanism where private and public-private arrangements seek to generate both economic and social returns (Oleksiak *et al.*, 2015). Such investments may come in the form of direct support of a business or project, indirectly through funds managed by an intermediary, or green or social impact bonds. Governments and foundations are often key partners whose participation helps leverage capital from private sources, creating a multiplier effect, though questions remain as to how such arrangements can be implemented in the conservation sector when an existing commodity (such as agriculture or fisheries) is not present (Olmsted, 2016).

Evidence

Socio-technological innovations play a key role for transformations towards sustainability. From the scenario reviews and nexus analyses we know that technological advances in the food system and agriculture are central to feeding the world's future population and enhancing the conservation and sustainable use of nature (5.3.2.1) and to improving water quality and water use efficiency and increase storage (5.3.2.4). Energy production from various bioenergy systems as well as climate change adaptations depend on further socio-technological developments (5.3.2.2). Resourcing growing cities while maintaining underpinning ecosystems and their biodiversity is a complex socio-technological challenge across spatial and social scales (5.3.2.6).

Responsible investment in industries that directly influence natural resources and assessment metrics that go beyond short-term economic profitability will be critical to achieving the nature-related SDGs in particular. Given the broad scope of socio-technological systems, such responsible investment strategies can contribute to the emergence of a new techno-economic paradigm of sustainability (Perez, 2002), if incentives and regulations are reconfigured according to the socioecological underpinnings of the global economy (5.4.2.1-5). First steps have already been achieved by acknowledging that unsustainable technology poses large and potentially unforeseeable risks to the ecological embeddings of societies (Altenburg & Assmann, 2017). Though not expanded upon here, these processes need to address cultural diversity, social justice and public interests (see 5.4.1.5; Beumer *et al.*, 2018).

Transformations of various sectors (including energy technology, transportation, and built infrastructure generally) are beginning to attend to climate change considerations but have yet to address as mainstream a comprehensive suite of biodiversity and ecosystem service considerations (CBD, 2010; Cowling *et al.*, 2008); if they are not addressed directly, such nature-related considerations are likely to be further undermined by technological and sectoral evolution (Gopalakrishnan *et al.*, 2017). Increasing returns from investments in socio-technological niche innovations entail increasing risks of promoting less sustainable technologies and/or institutions, since already funded projects are treated preferentially at the expense of potentially superior alternatives (Foxon, 2007).

The 'rebound' of efficiency gains can be tackled in the transition phase of an incremental innovation by taxation, regulation or other impulses for consumption change (see, for example, Herring & Roy, 2007). Here, sociocultural framings, norms, worldviews and relational values influence the outcomes of socio-technological innovations enormously. Nevertheless, these factors remain largely overlooked in studies on sustainable socio-technological transformations (see Beumer & Martens, 2010).

Socially responsible and impact investing sectors are growing rapidly (GIIN, 2017), though environmental and conservation projects represent a fraction of impact investments; and impact investments currently represent a tiny share of global private capital markets. The limited application to date in the conservation sector is due to a lack of investable projects at scale, as well as challenges assessing and attributing impact in complex ecological systems (Olmsted, 2016). While there are a few large and headline grabbing arrangements, such as the Seychelles debt swap that will result in 400,000 km^2 of marine protected areas in the coming 5 years, such outcomes take years of negotiation and involve an array of public and private partners (NatureVest, 2018). Impact investments need not be so complex, but such examples highlight the potential scale of impact.

Possible points of action

Socio-technological sustainability innovations can be stimulated by incentives (e.g., Costello *et al.*, 2008; Mulder *et al.*, 1999; see also 5.4.2.1), but can also be initiated in real world experiments (Liedtke *et al.*, 2015; Nevens & Roorda, 2014; see also 5.2). Technological enhancements in companies can be supported by new innovation methods (Gaziulusoy *et al.*, 2013). Furthermore, implementation of a precautionary approach encourages proactive orientations towards sustainability in socio-technological innovation processes (Leach *et al.*, 2010).

Since affordability is a key to diffusion of new technologies (e.g., Mazumdar-Shaw, 2017), diverse financial instruments, including public financing and sharing technologies, contribute to overcoming unsustainable socio-technological systems rapidly (Foxon & Pearson, 2008; Stirling, 2008; Technology Executive, 2017). Public deliberation and transparent decision-making which involve experts, stakeholders and interested citizens generates social robustness of envisioned changes (Bäckstrand, 2003) and helps to avoid technological and institutional dependencies (van den Daele, 2000).

Every transformation process in which new technologies are established generates winners and losers. This is not only true for species (Egli *et al.*, 2018), but also for groups and individuals (e.g., O'Brien & Leichenko, 2010). Blockades to sustainable socio-technological solutions and lock-ins might be considered as strategies for avoiding losses of socioeconomic status. Innovative changes in technological policy and regulation and in incentive structures could deepen and accelerate steps towards sustainable socio-technological systems by simultaneously addressing both the demand for and supply of innovation (Jaffe *et al.*, 2005).

While there has been increased emphasis on sustainability reporting, and efforts such as the Global Reporting Initiative aim to streamline and facilitate reporting, climate metrics receive significant attention and the lack of emphasis on ecological systems is of particular concern (Milne & Gray, 2013). A study of corporate commitments to reduce deforestation highlight the challenges to meeting targets due to obstacles including leakage, lack of transparency, traceability, and selective adoption (Lambin *et al.*, 2018). These authors and others recommend increasing partnerships and arrangements between NGOs, businesses, and governments to co-create solutions and work to reduce impacts. The emergence of legal arrangements to loosen profit-maximizing constraints of corporations have promoted social business and investments in long-term sustainability that may not have been viable previously. As consumers and investors demand transparency, communication of impact and information-sharing can hold organizations accountable. Coordinating efforts across the public and private sector can help develop relevant policy, regulation, and incentives that provides stability and confidence for business and investors in new technology and innovation (e.g., Dauvergne & Lister, 2012). Corporate targets can incentivize innovation in supply and value chains (e.g., improving transparency with new technologies). Effective transformation on the ground may require national level intervention, for example, policies to support small producers who may not otherwise be able to transition as quickly or effectively. Voluntary public commitments permit early movers to demonstrate a business case for sustainable transitions, which can be bolstered by public sector support (e.g., Tayleur *et al.*, 2017). Full-cost accounting and policy shifts including changing accounting rules to include natural capital as an asset class have been shown to facilitate long-term investment in ecosystem services (Municipal Natural Assets Initiative, 2017).

5.4.1.8 Education and transmission of indigenous and local knowledge

Education and knowledge transmission are often heralded as a route to sustainability through maintenance or change in behaviours and attitudes, but their role in sustainability is even more fundamental, as a precursor to well-functioning societies. Further, education will only serve either role if conceived much more broadly than as imparting information. Rather, education that leads to sustainable development and enduring change in knowledge, skills, attitudes, and/or values builds from existing understandings, fosters social learning, and embraces a "whole person" approach. Environmental education can enhance values such as connectedness, care, and kinship. Transmission of indigenous and local knowledge can serve all the roles above, including maintaining invaluable knowledge and experiences about ecological processes, but it is also a keystone to cultural integrity and the maintenance of collective identity.

Evidence

Education, as the broad transmission of knowledge and capabilities, is widely recognized as essential for stable, well-functioning societies (Nussbaum, 2000; Otto & Ziegler, 2010; Sen, 1999). Thus, education—*in and of itself*—is a crucial precursor of sustainability (Sachs, 2015). Though education systems have sometimes served to inculcate particular norms and attitudes (King & McGrath, 2004), some educators and scholars have for centuries recognized and taken steps to deal with the inherent ethical complexities of teaching to develop engaged citizens (e.g., Dewey, 1975; Hug, 1980).

A brief yet crucial point is the demonstrated importance of education for girls and women. Increased rates and quality of education for girls and women correlate with higher levels of gender equity and lower birth rates, both of which are components of pathways to sustainability (UNICEF, 2003; see also 5.4.1.2 and 5.4.1.4).

Beyond the crucial importance of indigenous and local knowledge for cultural integrity and identity, ensuring the transmission of this knowledge and practices is key to sustainable pathways. Over millennia, IPLCs have developed and integrated invaluable knowledge and experiences about ecological processes, environmental management, production systems, as well as institutions supporting the sustainable use of resources (Nadasdy, 2007; Taylor, 2009; Tuck *et al.*, 2014; Turner, 2005; Vickery & Hunter, 2016). Many landscapes around the world, and much global agrobiodiversity heritage, depend on the knowledge and cultural memory held by IPLCs and other farmers, hunters, fishers, foragers, herders, and pastoralists, etc. Continued transmission of these forms of knowledge in varied and culturally appropriate ways (Cajete, 1994) maintains alternatives for managing landscapes and seascapes sustainably (5.3.2.3; 5.4.1.5).

Emerging insights from western literatures on education appear to be converging with lessons from indigenous and local knowledge transmission. As a first example, research demonstrates that the "deficit model" of education and communication, which assumes that people would think and act differently if only they had the right information, is rarely effective at creating lasting attitudinal or behavioural change (Dietz & Stern, 2002; Kollmuss & Agyeman, 2002). More effective educational approaches—those that are more likely to foster fundamental and long-term change in knowledge, skills, attitudes, and/or values—encompass prior knowledge (e.g., existing understandings), social interaction (e.g., interpersonal relationships and collective learning), and affective as well as cognitive dimensions (e.g., emotional responses to what is learned; Heimlich & Ardoin, 2008; Wals, 2011). Based on these findings, fields related to environmental education, including nature conservation education and education for sustainable development, have moved away from an "information delivery" model to more integrated models that collaboratively explore the intricate links between environmental and social equity and empower learners as change agents.

Broad education and knowledge transmission literatures have identified that effective education, including that for sustainability, involves two interrelated components: process and content. The former is crucial, but often overlooked. Process involves the ways education is carried out, in other words, the approaches and how teaching and learning occur. Diverse theories of learning emphasize different aspects of the learning process (Merrian & Bierema, 2013). A few commonalities emerge, and three aspects of learning theory (detailed below) are particularly relevant to issues of sustainability.

The first commonality of learning theory is the importance of recognizing and responding to learners' context, experience, and existing understandings. A helpful metaphor here follows directly from constructivist learning theory, understanding is constructed from and upon "blocks" of what is already known and if existing understandings must be changed, that must be dealt with, not ignored. In sustainability-related education, this concept is paramount, it coincides with the importance of locally based solutions that account for diverse contexts.

A second commonality is the role that social interaction plays in learning. This focus on social dimensions of learning takes two primary forms: the idea that much learning occurs via observing others (Bandura & Walters, 1977; Rogoff *et al.*, 2003) and the idea that learning occurs collectively, in and by social groups (Rogoff, 1994; Wals, 2007). These social interactions may be particularly important for the transmission of indigenous and local knowledge (Berkes & Turner, 2006; Turner & Turner, 2008). The importance of social interaction for sustainability education manifests in many ways, including the strong role that social norms play in fostering sustainable behaviour (Miller & Prentice, 2016) and the substantial success of initiatives that engage social learning for sustainability (Wals, 2007).

A third commonality addresses the relevance of attending to the "whole person" in learning. The whole person approach emphasizes that education is about both cognitive and affective aspects of the learner, that education must think not only about cognitive development, but must also attend to the crucial role that emotion can play in learning (Podger *et al.*, 2010). This holistic approach has been central to education in IPLCs for millennia. These emotional aspects may be particularly important in sustainability-related education, which can involve strong emotions such as despair and hope (Hicks, 1998; Li & Monroe, 2017; Newman, 1996).

Content is the second pillar of sustainability education. Though content may seem more straightforward than process, decisions about content, what to include and exclude from educational initiatives, are crucial. Content encompasses knowledge, concepts, and skills that are relevant to sustainability. Content that is central to most recent frameworks of environmental and sustainability education includes the following: social justice and the centrality of equity to sustainability; participatory learning and engagement with local communities (both ecological and social); citizenship skills, such as knowledge and empowerment related to collaboration, dialogue, and democratic processes; interconnectedness and systems thinking; and attention to multiple scales (spatial, temporal, and organizational) (Tilbury, 2011).

Possible points of action

Given that a common challenge to sustainable behaviour is that people default to decision-making based only on technological or economic feasibility, sustainability-related education can develop understanding of the complexities of, and synergies between, the issues threatening planetary sustainability, and encourage consideration of complex options and trade-offs. The long timescales over which people's orientations and priorities become established, coupled with the many social and personal influences on these orientations and priorities, make study of the impact of sustainability-related education difficult. Even so, research suggests that time spent during childhood in outdoor or natural environments with respected adults can be an important motivator for learning about these complex issues and taking sustainability-related action in adulthood (Chawla & Cushing, 2007). Though results about the relations between connection to nature and behaviour are varied; connection to nature, which is often but not always established in childhood, in some cases correlates with increased pro-environmental behaviour (Geng *et al.*, 2015; Gosling & Williams, 2010; Mayer *et al.*, 2008).

For IPLCs, the educational system can be the basis for strengthening a political and cultural project that incorporates traditional and novel perspectives on management, use, and maintenance of existing resources in these communities. Some see an urgent need to recognize the importance and enhance the transmission of indigenous and local knowledge, both intergenerationally and among different societal groups, as a complement to mainstream education—including to maintain crucial relationships with nature and values of responsibility and stewardship associated with those (Chan *et al.*, 2016; Chan & Satterfield, 2016). Ideally, these two forms of knowledge can be integrated, but often formal education tends to be favoured and in some cases negates the value of local forms of knowledge. Education targeted at IPLCs can develop skills required to, for example, serve in government roles or innovate in fields such as production, trade, and management, *while maintaining traditions, values and culture*. At the same time, incorporating principles and content from indigenous and local knowledge would enrich and improve all education (McCarter *et al.*, 2014; World Bank, 2015).

Environmental education can lead to a variety of outcomes supportive of sustainability, including knowledge, attitudes, and skills (Stern *et al.*, 2014). It can also enhance values such as of connectedness, care, and kinship (Britto dos Santos & Gould, 2018). That said, the fields of environmental and sustainability education are home to many discussions of the extent to which education should explicitly encourage particular values or behaviours (Hug, 1980). Though opinions on the proper course of action differ, the most common approach is for environmental education to encourage active and informed citizenship. This citizenship inherently encompasses the ability to understand and assess one's own values (virtues and principles) and those of the society in which one lives (Tilbury, 2011). Increasing awareness of connectivity in the environmental crisis and new norms regarding interactions between humans and nature would support transformative change The goal of this work is to provide tools that allow people to engage in respectful, thoughtful, and informed negotiations toward decisions and actions that lead to a sustainable future (Huckle *et al.*, 1996; Tilbury & Wortman, 2004).

5.4.2 Levers for Sustainable Pathways

5.4.2.1 Strategic use of incentives and subsidies

Achieving SDGs and Aichi Biodiversity Targets will likely require a continued evolution of subsidies (including discontinuing harmful subsidies) and incentive programs to foster conservation and stewardship practices while cultivating appropriate norms and values. Such programs can be part of effective policy mixes, involving both positive and negative incentives through regulations and market-based instruments.

Background

While subsidies are a form of incentive, due to their prevalence as a policy tool and history of challenges, we see benefit in distinguishing them from other incentive types. Note also, that although incentive programs are often considered to trigger behaviour change by providing an incentive, a diverse body of literature strongly suggests that the incentive to conserve or restore may already exist and that 'incentive' programs may work best by removing financial and regulatory barriers (Kosoy *et al.*, 2007; Stoneham *et al.*, 2003; Wilcove & Lee, 2004).

Evidence

Many scenario and pathway analyses identified the importance of shifting incentive structures, either by removing perverse subsidies or adding new positive incentives, especially studies focused on climate action, energy systems, or water. For example, Schandl *et al.* (2016) explored the implications of imposing a global carbon price, which in their model created incentives for nations to invest in renewable energy generation. Carnicer & Peñuelas (2012) demonstrated the power of funds raised through small negative incentives, showing that a small global tax on financial transactions of 0.05% could provide funds required for widespread deployment of renewable energies. McCollum *et al.* (2012) concluded that incentive mechanisms are key to transforming the global energy system, including targeted subsidies to promote specific "no-regrets" options (e.g., microcredits and grants for low-income populations to buy low-emission biomass and low-emission biomass and Liquefied Petroleum Gas (LPG) stoves).

Subsidies and other so-called incentive programs are implemented to shift institutional and individual practices, which is a key component of successful pathways, under two conditions. The first is that such incentive programs are implemented as components of policy mixes (Barton *et al.*, 2014; Bennear & Stavins, 2007; Porras *et al.*, 2011), in which regulations are also employed to set norms and provide negative incentives. In some contexts, the incentive program or subsidy is the positive element that makes a regulation politically feasible, where the regulation is the key factor in shifting practice—e.g., as apparently the case for the national payments for environmental services (PES, or 'PSA' in Spanish) program and deforestation ban in Costa Rica (Daniels *et al.*, 2010; Fagan *et al.*, 2013; Legrand *et al.*, 2013; Morse *et al.*, 2009; Pfaff *et al.*, 2009; Porras *et al.*, 2013; Robalino *et al.*, 2015).

Incentive programs play especially helpful roles in pathways when executed so as to avoid the historic pitfalls resulting in adverse environmental consequences. The evidence from natural and social sciences reveals two broad classes of failings with regard to the role of incentives and subsidies in resource management. First, a large number of incentives and subsidies are intended to encourage employment and production but have unintended large-scale impacts on biodiversity and ecosystem services (e.g., Milazzo, 1998; Sumaila & Pauly, 2007). In addition to direct negative effects on ecosystems, by distorting market signals to boost production, some subsidies promote overproduction that can fuel overconsumption and drive a vicious cycle (5.4.1.2, 5.4.2.1).

Subsidies are important features of major industries and their environmental impacts. Concerning marine fish biodiversity, for instance, an estimated $35 billion in subsidies (30–40% of estimated gross revenues from the sector) is provided to the global fishing sector annually. Nearly 60% of this is classified as harmful subsidies, i.e., those that ultimately stimulate over-capacity and overfishing (Heymans *et al.*, 2011; Sumaila *et al.*, 2016). Agricultural subsidies intended to stimulate growth in domestic markets and competitiveness in exports have likewise led to unintended ecological consequences. Corn subsidies for biofuel in the United States increased corn production and decreased soy, significantly increasing global soy prices, incentivizing Amazon deforestation as soy-related land conversion dramatically increased in Brazil (Laurance, 2007; Westcott, 2007).

In many cases, even incentives and subsidies that are intended to encourage conservation and stewardship behaviours can result in unintended negative effects at either individual or collective scales (Chan *et al.*, 2017b; Vatn, 2010). A good example here are so-called buyback or decommissioning subsidies. Millazzo (1998) considered these to be 'green' subsidies because the goal of governments who implement buyback subsidies is to reduce fishing capacity in overfished fisheries. But what often happens is that vessels supposedly retired quickly seep back into the fishery (Holland *et al.*, 1999). Furthermore, fishers may anticipate the implementation of a buyback subsidy, which can motivate them to accumulate additional fishing capacity so they can sell it later for profit in a buyback programme (Clark *et al.*, 2005).

Incentives and subsidies intended to encourage conservation and stewardship actions can also backfire by crowding out inherent motivations and by assigning or reinforcing notions of rights and responsibilities that may be counterproductive for long-term sustainability (Chan *et al.*, 2017b; Vatn, 2010). There is strong experimental evidence that when people have inherent motivations to undertake an action beneficial for biodiversity and ecosystem services, the introduction of a monetary incentive can sometimes undermine those inherent motivations (Rode *et al.*, 2015), with potentially damaging consequences for long-term outcomes. However, incentive programs can also sometimes strengthen pre-existing motivations (i.e., 'crowd-in' inherent motivations; Rode *et al.*, 2015), and can be designed to do so while articulating and reinforcing values and norms of stewardship and responsibility (Chan *et al.*, 2017b).

Possible points of action

Strategic incentive programs are pertinent to a wide range of actors including private industry (e.g., forestry, agriculture, resource users of all kinds), NGOs, IPLCs, and governments of all kinds. Programs like payments for ecosystem services (PES) can be initiated by a wide range of actors for private gain and also improved environmental outcomes (Chan *et al.*, 2017a).

Programs providing incentives to undertake positive actions may be less prone to perverse consequences than those incentivizing stakeholders to refrain from taking damaging actions. Programs designed as flexible grants and awards may be more successful at articulating socially desirable rights and responsibilities, and 'crowding in' inherent motivations, than those that provide set payments for particular metrics (e.g., trees planted or not harvested) (Chan *et al.*, 2017a).

On a general level, the rules and regulations governing day-to-day decision-making can be adapted to create the right incentive structure for transformative changes (PBL, 2012). This would include abolishing perverse incentives (e.g., capacity enhancing subsidies: Sumaila *et al.*, 2016; Sumaila & Pauly, 2007; WBCSD, 2010) and introducing environmental factors in current pricing systems, e.g., green taxation (e.g., Daugbjerg & Pedersen, 2004).

5.4.2.2 Integrated management and cross-sectoral cooperation

Integrated management is widely recognized as an important mechanism to realize co-benefits and avoid trade-offs among competing priorities involving food, biodiversity conservation, freshwater, oceans and coasts, cities and energy, as analysed above (5.3.2). Achieving multiple SDGs and Aichi Biodiversity Targets entails policy coherence and the mainstreaming of environmental objectives across institutions within and among jurisdictions (e.g., fishing, transportation, shipping, oil and gas, renewable energy). Not all action towards a given objective will simultaneously benefit all other objectives, so an integrated approach enables harmonization that achieves targets without undermining others. Additionally, achieving global objectives will take coordinated action among disparate governing bodies.

Evidence

Almost all reviewed scenario and pathway studies called for integration and harmonization of policies and programs across sectors, agencies or jurisdictions. As an example, Fricko *et al.* (2016) concluded that an integrated approach to developing water, energy and climate policy is needed, especially given anticipated rapid growth in demand for energy and water. Quite differently, McCollum *et al.* (2012) included one pathway with integrated implementation of energy efficiency measures across all major sectors, leading to substantial reduction in energy demand. Integrated management is also widely recognized as key for availability, distribution and access to water (Cosgrove & Rijsberman, 2000), including as implemented by national governments across a broad policy spectrum including agriculture, food security, energy, industry, financing, environmental protection, public health and public security (WWAP, 2015).

Environmental management typically follows a series of demarcations most often along geopolitical boundaries and human constructs of the environment. First, management agencies are often constrained by jurisdictional boundaries that do not correspond with meaningful ecological transitions (McLeod & Leslie, 2009; Tallis *et al.*, 2010). Because of telecoupling across boundaries (discussed in 5.4.1.6), integrated policy and governance is key to managing effectively. For example, the Rocky Mountains of North America are managed by different countries' natural resources, environment and parks agencies (Canada and the USA), and by different provinces and states within these countries, without overarching agencies to consider management across these divisions. Cross-jurisdictional efforts like the Yellowstone to Yukon Conservation Initiative are important for gathering a wide range of stakeholders across this large region; transboundary management would go further, reconciling multiple management goals from multiple agencies for the Rocky Mountains (Levesque, 2001).

Second, ecosystems are often managed, and studied, separately (O'Neill, 2001). Perhaps the most prominent example of this type of division is the separate management of oceans versus land (Álvarez-Romero *et al.*, 2011). Despite clearly important connections in the land-sea interface—terrestrial processes affect oceans and marine processes affect the land (Álvarez-Romero *et al.*, 2011; Hocking & Reynolds, 2011; Tallis, 2009)—these divisions persist.

Third, management is often conducted separately on different important human uses, such as government departments dedicated to parks, protected species, fisheries, agriculture, energy and development (Becklumb, 2013). In some cases, this means that environmental impacts of overlapping human activities are managed separately; in other cases (e.g., protected areas), multiple activities are managed simultaneously, but often only within tight boundaries whereas environmental impacts transcend these. Environmental impacts and risks often stem from a variety of different activities, but accumulate (Halpern *et al.*, 2008). By dividing environment management according to different uses and different goals, important interactions among ecosystem components may be ignored. For example, management plans targeting recovery of predators or higher trophic level fisheries will be more effective if management also targets recovery of prey species (Samhouri *et al.*, 2017).

Finally, paradigms of environmental management are marked by conceptual divisions, whose integration would also help achieve sustainability objectives. For decades, western environmental management has treated human interaction with the environment mainly as a source of negative impacts, when in fact humans are in many cases integral components beneficial to ecosystems functioning (Hendry *et al.*, 2017; Higgs, 2017). Human activities often can transform otherwise inhospitable ecosystems to productive food growing habitats (Higgs, 2017), and fishing activities, if regulated, can sustain fish populations for harvest (Dowie, 2009; Jacobsen *et al.*, 2017). Yet, the view that humans are exogenous to natural systems has led to a series of important negative effects. As discussed above (5.4.1.5), there are numerous examples of conservation and management agencies, with power and authority over local institutions, that have moved to displace local populations from the ecosystems that, in many cases, are conserved because of them (Dowie, 2009), discrediting local knowledge about ecosystems management (Fischer, 2000), and imposing top-down regulations over institutions that have co-evolved with local ecosystem dynamics (Ostrom, 1990). Management mechanisms to attend to local concerns and integrate local knowledge can both provide valuable information and increase legitimacy and effectiveness of management.

Siloed management explicitly excludes interactions that can affect management goals. One example is the independent management of shipping, energy production, and coastal development, and the cumulative impacts this has had on the southern resident orca ('killer whale') population (Ayres *et al.*, 2012; Murray *et al.*, 2016) in the Salish Sea (in southeastern British Columbia, Canada and northern Washington State, USA). Incorporating risks to species and systems that these whales depend on can greatly increase understanding of risk (e.g., Murray *et al.*, 2016). In most cases, however, knowledge of risks to ecosystem services deriving from different human activities and infrastructure is piecemeal and insufficient for ecosystem-based management (Mach *et al.*, 2015). For long-term sustainability of resources and environments, cross-sectoral management is key to addressing multiple goals (Harrison *et al.*, 2018).

Recent analysis of interrelationships between SDG targets provides insights into how to integrate policy towards achieving multiple goals. For instance, it suggests that achieving the ocean targets within SDG 14 has the potential to contribute to all other SDGs (Singh *et al.*, 2018). Moreover, ending overfishing and illegal fishing alone (SDG 14.4) can contribute to several other SDG targets. Increasing economic benefits to Small Island Developing States (SDG 14.7) could contribute to a suite of SDGs, depending on policy implementation and how benefits are distributed (e.g., whether marine development helps fund education (5.4.1.8)). In contrast, increasing the coverage of marine protected areas (SDG 14.5) can trigger trade-offs with other SDGs among the SDG 14 targets, because MPAs can limit access to needed local resources and decrease local peoples political power. However, these trade-offs can be avoided through proper consultation and implementation with local people (5.4.1.5), as in integrative policy planning.

Thus, integrated management is widely understood as a key mechanism to account for interactions, trade-offs and synergies between SDGs. Global scenarios underline this even though many challenges are beyond the capability of integrated assessment models (IAMs) and require additional consideration (e.g., globalization processes such as trade, migration or large-scale land acquisitions including land-grabbing).

Possible points of action

Integrating management across sectors is pertinent to a wide range of actors including private industry (e.g., forestry, agriculture, resource users of all kinds), NGOs (e.g., land trusts), IPLCs, and governments of all kinds. For example, diversified but integrated business models for forestry or farming operations may yield greater and more stable revenues as well as long-term environmental benefits (harvesting resources but also hosting tourists and other recreators, and participating in ecosystem service markets and incentive programs). However, integrated management approaches will be much more likely when encouraged or required by underlying regulations and influential private and NGO actors (e.g., insurance and reinsurance companies, companies exerting control over value chains, investors, lenders, certification systems and other standards).

Management efforts with cross-boundary provisions are often helpful (Levesque, 2001; McLeod & Leslie, 2009; Tallis *et al.*, 2010). Management across boundaries can also contribute to and benefit from Sustainable Development Goal target 17.16 (global partnerships for sustainable development, complemented by multi-stakeholder partnerships).

Laws requiring that management and policy (including protected areas and restoration efforts) state and reflect important spatial and temporal social-ecological dynamics may enable long-term cross-sectoral benefits (Kliot *et al.*, 2001; McLeod & Leslie, 2009).

Co-management arrangements and partnerships with informal environmental experts and users, may enable integration of important and time-sensitive information, enhancing legitimacy of and compliance for management plans (Dowie, 2009; Fischer, 2000).

Management plans may be more successful if they reflect multiple goals, potentially including the state of a resource/population as well as the uses of that resource (Lindenmayer *et al.*, 2000; McLeod & Leslie, 2009; Rice & Rochet, 2005).

5.4.2.3 Pre-emptive action and precaution in response to emerging threats

Sustainable pathways generally entail addressing risks well before system-specific proof of impact has been established.

Evidence

The scenario and pathway studies consulted involve a timely response to a variety of risks facing biodiversity and ecosystem services, either explicitly or implicitly. While scenarios do not generally detail the process of scientific study or the demonstration of proof, based on the long time lag between scientific focus on a phenomenon and consensus about causality, let alone proof (Oreskes, 2004), we can infer that most scenarios entail managing risky activities before establishment of proof that those activities cause particular harms. Furthermore, backcasting studies sometimes indicate that certain interventions require early implementation (Brunner *et al.*, 2016).

The need for early, precautionary action is also supported by arguments from theory, supported by a wide range of associated evidence. Many important challenges facing nature and its contributions to people involve several key complications of complex adaptive systems (numerous time-lags in social and ecological subsystems, multi-causality that impedes proof, and nonlinear responses that may appear slow until a threshold is passed, after which reversal may be impossible or impracticable; for more, see 5.4.2.4). These complications mean that empirical demonstration of system-specific cause-and-effect relationships is difficult (sometimes impossible), that it may take a long time, and that major and near-irreversible harms may have occurred before proof is established (e.g., Burgess *et al.*, 2013).

The various components of this argument from theory have considerable empirical backing. First, there is abundant evidence of time lags between ecological degradation and their societal consequences (e.g., Jackson *et al.*, 2001). This is exacerbated by interacting regime shifts at multiple scales (Leadley *et al.*, 2014). Second, ample evidence demonstrates that many changes in biodiversity and ecosystem services are the result of simultaneous action of diverse processes operating at multiple scales, which would impede the demonstration of any one factor as the cause of a given decline (e.g., Graham *et al.*, 2013; Levin, 1992; Marmorek *et al.*, 2011; Schindler *et al.*, 2003). Third, many systems exhibit thresholds (e.g., Folke *et al.*, 2004; Hastings & Wysham, 2010) combined with path-dependency (hysteresis, e.g., Graham *et al.*, 2015; Hughes *et al.*, 2010), which are difficult to reverse (Walker & Meyers, 2004) and the difficulty reducing stressors sufficiently to encourage reversal (Graham *et al.*, 2013).

This drawback of reactive management is particularly relevant for managing effects on “slow” system variables (variables that historically would generally have changed slowly, on evolutionary timescales), such as habitat availability. Such “slow” variables are often secondary concerns for stakeholders and managers more concerned with “fast” variables, such as annual fishery productivity, except where the habitat itself is widely appreciated (e.g., coral reefs; Pratchett *et al.*, 2014). However, should a slow variable pass a threshold, the system may shift rapidly to an alternate state, thus changing the dynamics of fast variables (Walker *et al.*, 2012). In such situations, even if the slow variable is restored to its previous level, the fast variables may be unable to return to their previous configurations due to the effects of path dependency.

The management of risks to slow variables is a key aspect of governing for resilience (Folke *et al.*, 2004; see also 5.4.2.4). However, as indicated above, it can be very costly if management waits for system change before acting to identify and manage risks. Due to their generally slower rates of change and susceptibility to threshold effects, slow variables in particular may often require precautionary approaches. This is the rationale for this specific lever as an issue that is separate but complementary to both integrated management (5.4.2.2) and management for resilience, adaptation, and transformation (5.4.2.4).

Possible points of action

Based on the above, it would appear that management, policies, and laws that place a strong burden of proof for the establishment of harm before requiring action are not conducive to long-term sustainability. Accordingly, a precautionary approach can be embedded in resource management and a diverse set of environmental policies and laws (e.g., Europe’s Registration, Evaluation, and Authorization of CHemicals (REACH) regulations). This point is pertinent to a wide range of actors including private industry (e.g., forestry, agriculture, resource users of all kinds), NGOs (e.g., land trusts), IPLCs, and governments of all kinds. However, precautionary approaches will be much more likely when encouraged or required by underlying regulations and influential private and NGO actors (e.g., insurance and reinsurance companies, companies exerting control over value chains, investors, lenders, certification systems and other standards).

Precautionary approaches have been subject of much debate (Stirling, 2007), but they have become accepted aspects of management in some respects. A precautionary approach is one of the principles of the UN’s voluntary Code of Conduct for Responsible Fisheries, for example, and thus has become established as a commonly invoked tenet of fisheries management. In the Alaska groundfish fisheries, for example, precaution has been integrated into the process by which allowable catches are determined, with estimates of maximum yield serving as a limit to be avoided rather than a target to be achieved; allowable catches are reduced from this limit following a series of steps that buffer against uncertainty, requiring greater reductions in catches in situations of less information (Witherell *et al.*, 2000).

A key precautionary mechanism is the maintenance of diversity. For instance, genetic diversity within and among species contributes substantially to ecosystem services, just as a diversity of species do. Genetic diversity within species maintains the potential for them to respond adaptively to environmental changes, thus facilitating and improving persistence in the face of environmental change. Diversity also maintains options for the future (NCP18).

The precautionary approach was not necessarily formulated to address issues of complex adaptive system management. However, it does provide a framework for the management of risks and uncertainty associated with complex social-ecological systems (Levin *et al.*, 2013), and thus represents an existing policy lever by which the challenges of complex adaptive system management may be addressed. Integrated Ecosystem Assessment may be useful for identifying appropriate early and pre-emptive actions (Levin & Möllmann, 2015), via a formal synthesis and quantitative analysis of relevant natural and socioeconomic factors in relation to specified ecosystem management objectives. Regardless, it is particularly important to avoid inaction (DeFries & Nagendra, 2017).

5.4.2.4 Management for resilience, uncertainty, adaptation, and transformation

Policies, programs and management agencies that seek optimal outcomes while assuming linear or equilibrium ecosystem dynamics are likely to result in undesirable surprises, as nature often operates in nonlinear ways. Policies and programs that are designed to be robust to uncertainty and to cultivate system resilience, including at the expense of program efficiency, may be more effective and efficient in the long term.

Evidence

Environmental management that seeks to maximize the extraction of a resource or population often backfires. System shocks and sudden changes can and generally will undermine effective management (Chapin III *et al.*, 2009). There are three ways in which the long term stability of an ecosystem can change that affect nature's contributions to people.

First, the consequences of ecological degradation may not be felt immediately but may manifest after a time lag. Historical overfishing has been linked to the collapse of coastal ecosystems, limiting their ability to provide resources for people (Jackson *et al.*, 2001). Similarly, the historic culling of wolves in North America has led to an abundance of coyotes and mesopredators, which has led to economic costs for ranching through predation on livestock (Prugh *et al.*, 2009).

Second, management to optimize a single goal can leave ecosystems vulnerable to disturbances. The literature on agriculture and forestry industry is replete with evidence of how management to maximize yield renders ecosystems vulnerable to pests and diseases (Meehan & Gratton, 2015; Taylor & Carroll, 2003). Future shocks to ecosystems in the form of invasive species and diseases can pose long term risks to managed ecosystems. The mountain pine beetle epidemic is a prime example, where management of forest landscapes for a single primary goal (timber extraction) resulted in monocultures of even-aged trees that facilitated a massive infestation that threatened both forest ecosystems and the forestry industry in western North America (Li *et al.*, 2005; Safranyik & Carroll, 2006). Often, this vulnerability to disturbance is due to managing ecosystems with little species and structural diversity (Meehan & Gratton, 2015). Conversely, there is ample evidence to show that incorporating ecological diversity in managed ecosystems can protect against diverse shocks and help maintain ecosystem services (Duffy, 2009; Oliver *et al.*, 2015; Tilman *et al.*, 2006a).

Third, many systems exhibit thresholds of change, meaning that the build-up of human pressure may lead to sudden large changes in an ecosystem (Boettiger & Hastings, 2013). These 'tipping points' and ecosystem state changes have been documented on land and sea (Folke *et al.*, 2004; Hastings & Wysham, 2010), and may be accompanied by 'hysteresis effects', whereby a change in ecosystem state is difficult to reverse because of path-dependency (Graham *et al.*, 2015; Hughes *et al.*, 2010; Walker & Meyers, 2004; see also 5.4.2.3). Ecological state changes can occur at multiple scales and interact, which only increases their severity and difficulty in reversing (Leadley *et al.*, 2014), increasing the importance of managing more broadly for resilience, transformation and uncertainty.

Many case studies point to state changes being a result of multiple processes operating at multiple scales, impeding the identification of any single factor as the cause of a deleterious change (Graham *et al.*, 2013; Levin, 1992; Schindler *et al.*, 2003). Changes to Earth's climate, landscapes, and seascapes are the result of a growing human imprint, and the cumulative impacts of human actions can be more important as drivers of change than any single action (Halpern *et al.*, 2015). Research on the major drivers of tipping points for ecosystems and ecosystem services often points to interactions between emerging climate change and local human pressures, indicating that some risks posed by dramatic ecological changes may be more prevalent in the future (Halpern *et al.*, 2015; Rocha *et al.*, 2015). Thus, management that explicitly accounts for nonlinear dynamics will be more important than ever.

Possible points of action

Management that includes goals to reduce vulnerability to long term shocks and tipping points may be more effective at preventing or mitigating disasters, thus reducing the waste of resources associated with recovery efforts and accruing private benefits as well as more diffuse public ones (both social and ecological). In contrast, management focused principally on optimizing resources or populations may achieve short-term gains at the expense of long-term productivity and stability.

As with early action (5.4.2.3), managing for resilience, uncertainty, adaptation and transformation is pertinent to a wide range of actors including private industry (e.g., forestry, agriculture, resource users of all kinds), NGOs (e.g., land trusts), IPLCs, and governments of all kinds. Again, resilience-focused approaches will be much more likely when encouraged or required by underlying regulations and influential private and NGO actors (e.g., insurance and reinsurance companies, companies exerting control over value chains, investors, lenders, certification systems and other standards).

Management may be more effective if it explicitly considers how the underlying ecology and physical processes support specific management goals, and the major threats to these goals (Kelly *et al.*, 2015). The consideration of nonlinear ecosystem dynamics provides vital insights into appropriate timings, windows of opportunities and risks and the financial viability of investments in ecosystem management (Sietz *et al.*, 2017). For example, by linking nonlinear ecosystem behaviour to an economic evaluation of land management options, opportunities and challenges have been presented for cost-efficiently restoring or maintaining land ecosystems that are rich in biodiversity and help to mitigate climate change. Additionally, adapting to detrimental changes will require an understanding of how ecological change affects socioeconomic conditions, and effective ways that people in specific contexts can cope with changes, such as modifying growing seasons in response to climate change, or understanding how environmental change affects the ability of indigenous groups to harvest in traditional manners (Savo *et al.*, 2016).

Inherent and systemic uncertainties (time lags, tipping points, interacting mechanisms of change) imply that management can benefit from an adaptive process, whereby learning from ongoing management actions reduce uncertainty and refine management goals (Armitage *et al.*, 2009; Walters, 1986). The "learning by doing" approach of adaptive management is effective in many instances as a operational strategy to managing under uncertainty.

Biggs *et al.* (2012) offer a set of general recommendations for building resilience of ecosystem services, including maintaining diversity and redundancy in both ecological and governance aspects; understanding and managing connectivity, recognizing that there may also be negative effects like disease; managing feedback mechanisms and 'slow' variables important to nature's contributions to people, including monitoring and adaptive management; accounting for complexity in scenarios and planning, including nonlinearity and critical thresholds; promoting learning, participation, and polycentric governance; and enabling the self-organization of agents of change.

5.4.2.5 Rule of law and implementation of environmental policies

Strengthening the rule of law is a vital prerequisite to reducing biodiversity loss and protecting human and ecosystem health (and thus the interests of the public and future generations from incursion by private interests). Stronger international laws, constitutions, and domestic environmental law and policy frameworks, as well as improved implementation and enforcement of existing ones, are necessary to protect nature and its contributions to people. Respecting differences in context, much can be learned from legislation, policies, and instruments with demonstrated successes, while still maintaining opportunities for regulatory experimentation and innovation.

Background

Over the past fifty years, every nation in the world has ratified international environmental laws, passed environmental laws, and developed environmental policies (see for instance chapters 3 and 6). In some countries, these rules have contributed to substantial progress on particular issues. In other countries, these rules have had little or no discernible effect. Despite a proliferation of both international and domestic environmental laws, global environmental problems, including biodiversity loss, climate change, and the breaching of planetary boundaries, continue to worsen.

Evidence

Good governance, respect for the rule of law, and reducing corruption are prerequisites to sustainable development (Morita & Zaelke, 2005). There is a strong correlation between a country's performance on the Rule of Law Index (World Justice Project, 2016) and the Environmental Performance Index (Yale Center for Environmental Law and Policy *et al.*, 2016). For example, the top ten countries in the Rule of Law Index have an average ranking on the EPI of 14.6, while the bottom ten countries in the Rule of Law Index have an average EPI ranking of 126.5 (World Justice Project, 2016; Yale Center for Environmental Law and Policy *et al.*, 2016). From tackling illegal logging to implementing biodiversity laws, strengthening the rule of law is essential (Schmitz, 2016; Wang & McBeath, 2017).

It is widely acknowledged that international agreements intended to protect the planet's ozone layer, beginning with the Vienna Convention for the Protection of the Ozone Layer in 1985, have succeeded in addressing this threat to biodiversity (Fabian & Dameris, 2014). However, international treaties on biodiversity and climate change, while contributing to progress in some areas, have fallen short of achieving their objectives (Kim & Mackey, 2014; Le Prestre, 2017; Rosen, 2015).

Constitutional protections for nature, biodiversity, and endangered species have contributed to conservation successes (Boyd, 2011; Daly & May, 2016; Jeffords & Minkler, 2016). Specific examples include Brazil's extensive constitutional environmental provisions (Mattei & Boratti, 2017), Bhutan's requirement that 60 per cent of forests be protected (Bruggeman *et al.*, 2016), and Ecuador's recognition of the rights of nature (Kauffman & Martin, 2017).

Strong laws intended to protect endangered species (e.g., US Endangered Species Act, Costa Rica's Biodiversity Act) have the potential to not only stem the decline of individual species but also achieve their recovery to healthy population levels (Suckling *et al.*, 2012). Weaker laws (e.g., Canada's Species at Risk Act, Australia's Environment Protection and Biodiversity Conservation Act), less rigorously implemented and enforced, are less likely to achieve recovery goals (Hutchings *et al.*, 2016; McDonald *et al.*, 2015; Mooers *et al.*, 2010; Waples *et al.*, 2013). Policies and programs also have an important complementary role in protecting biodiversity, from monitoring and evaluating wildlife populations to conservation agreements with landowners.

Effective management of human activities within protected areas is also vital to conserving biological diversity (Watson *et al.*, 2014). This applies to the regulation of both legal activities (e.g. ecotourism, recreation) and illegal activities (e.g. poaching, industrial resource exploitation).

Possible points of action

The many scenarios evaluated here recognize that, over the long-term, transformation involves legislations (and incentives) that nurture a shift from linear to circular economies (that is from pathways by which resources are extracted, manufactured into goods, then lost as waste to circular ones based on natural systems that recycle, re-use, and re-create with no waste). This is crucial for several leverage points (5.4.1.2, 5.4.1.6, 5.4.1.7). Innovative legislation and policies approaches to fostering circular economies are appearing in places as diverse as Ontario, the EU, Japan, and China (Ghisellini *et al.*, 2016). These regulatory tools would of course include laws and policies that support the shift from fossil fuels to renewable energy (Fischer & Fox, 2012; Jaffe *et al.*, 2005; Raymond, 2016).

Constitutions have particular force, and their possible amendments can help convey that governments, businesses, and individuals have a responsibility to protect and conserve biodiversity, and that individuals have the right to live in a healthy and ecologically balanced environment (Boyd, 2011). We are also increasingly learning from the experiences at various scales of governance (from municipal to international) that are recognizing the rights of nature, as in Bolivia and New Zealand, and many municipalities elsewhere (Boyd, 2018).

Equally important, however, is addressing corruption in all countries, especially that directly related to the unsustainable use of natural resources. In some regions, curbing corruption alone could have significant positive impact for biodiversity (Stacey, 2018), particularly in countries that are home to biodiversity hotspots, have weak government presence, or are experiencing expansion of commodity production.

5.4.3 Putting It Together: Joint Action of Levers on Leverage Points

Although these various actions and changes may seem insurmountable when approached separately, one action may remove barriers associated with another, potentially having mutually reinforcing positive effects. Accordingly, and perhaps counterintuitively, multiple actions may be successfully undertaken more easily than individual actions, as illustrated by a series of case studies.

5.4.3.1 The Whole Is Easier than the Sum of Its Parts: Six Case Studies

Namibia, Sweden, Costa Rica, the US, the Seychelles, and New Zealand are among the countries that have successfully integrated multiple approaches in protecting biodiversity and ecosystem services. To be clear, these are only specific examples of innovative leadership to illustrate the importance of addressing multiple components and drivers affecting nature and people. There are also important examples of regulatory interventions operating at other scales and in different manners. For example, regional initiatives can have important effects, including via market-based initiatives that affect investment and industrial production by putting a price on pollution, particularly when framed around positive values of collective benefit (Raymond, 2016). Similarly, there are countless examples of local initiatives that have proven effective, from bylaws restricting pesticide use for cosmetic purposes to bans on plastic bags and other single-use plastic items.

Namibia's success with community-based conservation illustrates many of the above levers and how they can work together. Following independence from South Africa in 1990, Namibia's new government passed progressive legislation in 1996 that devolved user rights regarding nature (in particular wildlife) to local communities (5.4.2.5, Law; 5.4.1.5, Involving local communities).

This change in governance allowed communities to register their traditional lands as conservancies, providing them with both the legal right and the legal responsibility to manage their customary landholdings for the sustainable flow of benefits from wildlife and other natural resources. The proliferation of conservancies—from 4 in 1998 to 83 at present—has resulted in increased levels of financial benefits to the rural poor (Jones *et al.*, 2012; Naidoo *et al.*, 2016), recovering populations of wildlife (Naidoo *et al.*, 2011), a tremendous increase in the amount of land under conservation management (MET/NACSO, 2018), and the reconnection of a link between Indigenous Peoples and wildlife that spans thousands of years of joint history (5.4.1.2, Visions of a good quality of life). Governance decisions were the overall platform for the conservation successes that followed, with subsequent innovative linkages between local communities and international markets for tourism and plant products providing the tangible mechanisms by which local people have benefited from their natural resources (5.4.1.7, Technology and innovation; Barnes *et al.*, 2002). While community-based conservation has helped take a step towards improving the dramatic inequality between the marginalized rural poor and wealthier ranchers and urbanites in Namibia (5.4.1.4, Inequalities), considerable threats nevertheless remain that could hamper further gains. These include increased levels of human-wildlife conflict (Kahler & Gore, 2015), incentive structures (5.4.2.1) that are preventing the full sociocultural, economic, or biophysical values of wildlife from being unlocked (e.g., subsidies and political power dynamics related to livestock and mineral extraction; Muntifering *et al.*, 2017) and competing demands for land that are not evaluated in a synthetic way by governments at various levels of responsibility (5.4.2.2, Integrated management/governance). Nevertheless, the successes seen in Namibia demonstrate that conservation by local communities on their lands can lead to gains both for people and for wildlife.

Sweden has been a global leader on issues ranging from climate change to toxic substances, ranked fifth on the Yale Environmental Performance Index in 2018 (Yale Center for Environmental Law and Policy (YCELP) *et al.*, 2018), and is proactively discussing what a future without economic growth would look like (Boyd, 2015). In 1999, the Swedish Environmental Code established a goal of solving all of the country's environmental problems over the course of a single generation (Government of Sweden, 2000). Sweden has recalibrated its economy by imposing taxes on pollution, pesticides, and waste to reduce levels of these undesired items (5.4.2.1, Incentives and subsidies; 5.4.1.3, Behaviour change) (Wossink & Feitshans, 2000). Sweden has reduced sulphur dioxide emissions by ninety per cent (in part due to a tax on emissions), cut greenhouse gas emissions by more than 20 per cent since 1990 (in part due to a high carbon tax), contributing to improved quality of life (cleaner air, safer streets, better public transit, healthier people, and more comfortable buildings). Sweden's long-term goal is to be fossil fuel free by 2050. They were the first country in the world to take strong regulatory action on polybrominated diphenyl esters (PBDEs) after researchers discovered rapidly rising levels of these flame retardant chemicals in women's breast milk (5.4.2.3, Early or precautionary action) (Darnerud *et al.*, 2015). Sweden has created timelines for eliminating the use of a broad range of toxic substances including mercury, lead, carcinogens, and chemicals that harm reproduction (5.4.2.3) (Swedish Environmental Protection Agency, 2005). They consistently rank as one of the most generous countries in the world, dedicating one per cent of their annual GDP as Official Development Assistance to help the world's poorest nations (5.4.1.4, Inequalities) (OECD, 2018). This is more than three times the level of foreign aid provided by Canadian and American governments.

Recently, Sweden recognized that some of their environmental solutions actually exported problems to other countries (i.e., leakage or spillover impacts) (Swedish Environmental Protection Agency, 2011). For example, reduced levels of logging in Swedish forests were offset by rising lumber and paper imports from countries with more biodiverse forests. Declining oil use was achieved, in part, through rising imports of biofuels from Brazil, with adverse effects on tropical forests. Sweden now recognizes that today's levels of consumption in wealthy countries need to be reduced to alleviate pressure on overexploited planetary ecosystems (5.4.1.2, Consumption) (Swedish Environmental Protection Agency, 2011). To their credit, Sweden revised its goal of achieving sustainability within one generation to state "the overall goal of environmental policy [is] to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, *and this should be done without increasing environmental and health problems outside Sweden's borders*" (5.4.1.6, Telecoupling; 5.4.2.5, Law) (Swedish Environmental Protection Agency, 2013). To achieve this goal, the Swedish government observed that "policy instruments and measures must be designed in such a way that Sweden does not export environmental problems" but rather solves them through changing patterns of production and consumption (5.4.1.2, Consumption; 5.4.1.6, Telecoupling) (Swedish Environmental Protection Agency, 2011).

Costa Rica is widely recognized as an environmental leader, as a result of decades of determined effort including the key turning point of constitutional recognition of the right to a healthy environment in 1994 (5.4.2.5, Law; 5.4.1.5, Human rights and Indigenous peoples' participation) (Boyd, 2011). This small Latin American nation has enacted and implemented strong laws (such as the award-winning Law on Biodiversity, which recognizes nature's intrinsic value), placed more than one quarter of its land in parks and protected areas, and reversed the trend of deforestation (5.4.2.5, Law) (Hanry-knop, 2017). Impressively, Costa

Rica produces 99% of its electricity from renewable energy sources including hydroelectricity, geothermal, wind, and solar (5.4.2.4, Managing for resilience; 5.4.1.7, Technology and innovation) (Hanry-knop, 2017). Costa Rican laws prohibit open pit mining and offshore oil and gas development (5.4.2.5, Law). The country has a national carbon tax whose revenues are dedicated to helping small-scale farmers in reforestation and habitat protection (5.4.2.1, Incentives and subsidies). This national payment for ecosystem services program that has been shown to leverage existing inherent motivations for conservation (5.4.1.3, Enlisting values) (Kosoy *et al.*, 2007).

In 1948, Costa Rica decided to disband its military and invest the money saved in education and health care (5.4.1.2, Visions of a good quality of life; 5.4.1.8, Education) (Abarca & Ramirez, 2018). The country now enjoys high levels of literacy (97.4 per cent) and long life expectancy (79.6 years) (UNDESA, 2017; UNESCO, 2018). Twenty years ago, Costa Rica's leading exports were coffee and bananas. Today Costa Rica's most valuable exports are computer chips and medical prosthetics, as corporations have located manufacturing facilities to take advantage of the country's educated workforce, clean air, and clean water. Costa Rica is the top-ranked country in the world on the Happy Planet Index, which integrates measures of life expectancy, self-rated happiness, and per capita ecological footprints (HPI, 2016). The national expression "pura vida" or the pure life, refers to achieving happiness in harmony with nature, a goal also established in the 2009 constitution of Ecuador (5.4.1.2, Visions of a good quality of life).

The effectiveness of strong legal protection for biodiversity is illustrated by the United States, which initially passed a law to protect endangered species in 1967, revised it in 1969, and introduced its most powerful elements, which remain in place today, in 1973 (5.4.2.5, Law) (Boyd, 2018). The law compelled the United States to host an international meeting intended to spark the development of a treaty to protect endangered species. The meeting led to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In a lawsuit involving the construction of a dam that threatened and endangered fish called the snail darter, the US Supreme Court ruled that "The plain intent of Congress in enacting the *Endangered Species Act* was to halt and reverse the trend toward species extinction, whatever the cost" (5.4.2.5; U.S. Supreme Court, 1978). The law's bold regulatory power was also alienating to some landowners, however, who resented the state imposition of restrictions on individuals and firms who happened to host species at risk. Arguably, the Act's survival in Congress and its ability to garner the willing participation of landowners depended upon regulatory innovation that removed disincentives for reporting species at risk and provided incentives for protection and restoration (5.4.1.3 Values, agency; 5.4.2.1 Incentives) through the Safe Harbour Agreement and mitigation banking (Bonnie, 1999; Fox *et al.*, 2006; Fox & Nino-Murcia, 2005). These programs enabled landowners to act in accordance with pre-existing stewardship values (5.4.1.3, Values) (Wilcove & Lee, 2004).

More than 30 species have been removed from the US endangered species list because their populations have recovered, including the bald eagle, peregrine falcon, gray whale, grizzly bear, gray wolf, brown pelican, Steller sea lion, American alligator, a snake, a flycatcher, a flying squirrel, a lizard, an orchid, and a daisy (U.S. Fish & Wildlife Service, 2018). Bald eagle populations in the lower 48 states rebounded from a low of roughly 400 nesting pairs in the early 1960s to more than 10,000 today. Keys to the bald eagle's recovery include prohibitions on hunting, banning the pesticide DDT, and protecting critical habitat, such as nesting sites (5.4.2.5, Law) (Doub, 2013). The US Center for Biological Diversity identified more than 20 species whose populations increased by more than 1,000 per cent in recent decades (Suckling *et al.*, 2012). There was a 2,206% increase in nesting Atlantic green sea turtle females on Florida beaches. The California least tern enjoyed a 2,819% increase in nesting pairs. The San Miguel island fox population increased 3,830%. Numbers of the El Segundo blue butterfly increased 22,312%. Studies indicate that roughly 90% of species listed under the US Endangered Species Act are on track to meet their recovery targets by the projected deadline (Suckling *et al.*, 2012).

The Seychelles is among the world's leaders in the percentage of its land that is designated as protected, at over 42 per cent (World Bank, 2018). The Seychelles Islands amended their constitution in 1993 to recognize that citizens have the right to live in a healthy environment, and that government has a responsibility to protect the environment (5.4.2.5, Law; 5.4.1.5, Human rights) (Boyd, 2011). In a case involving the prosecution of eight individuals for unlawful possession of meat from protected species, including sea turtles and boobies, the Supreme Court of Seychelles referred to the constitutional right in interpreting the *Wild Animals and Birds Protection Act*. The court wrote: "The right to a healthy environment has become a fundamental right. In Seychelles that right extends to the Management of Marine Resources as well as protected Land or Sea Birds" (5.4.2.5, Law) (Seychelles Legal Information Institute, 2004). Seychelles was recognized by the United Nations Environment Program as a Center for Excellence in its approach towards coastal development with reference to both efforts to protect coral reefs and a successful dolphin-free tuna industry (5.4.2.2, Integrated management; 5.4.2.4, Managing for resilience) (CountryWatch, 2018). Finally, air quality in the Seychelles is ranked number one according to the Yale Environmental Performance Index (Yale Center for Environmental Law and Policy *et al.*, 2016).

New Zealand is the highest rated non-European country on the EPI, ranked 17th in 2018 (Yale Center for Environmental Law and Policy (YCELP) *et al.*, 2018). More than 32 per cent of New Zealand's land enjoys legal protection (World Bank, 2018). New Zealand is the first country in the world to pass laws that transfer ownership of land from humans to nature (5.4.2.5, Law; 5.4.1.5, Human rights and conservation) (Boyd, 2018). Two recent laws, governing the Whanganui River and an area previously designated as Te Urewera National Park, designate these natural systems as legal persons with specific rights (New Zealand Government, 2017). For example, the Te Urewera ecosystem has the right to protection of its biological diversity, ecological integrity, and cultural heritage in perpetuity (Te Urewera Act, s. 4). These innovative laws that may eventually change the way New Zealanders relate to nature, from one in which we treat nature as a commodity that we own, towards nature as a community to which we belong (5.4.1.3, Behaviour change; 5.4.2.4, Managing for resilience). In each case, the laws establish a guardian, comprised of Indigenous Maori representatives and government representatives, to ensure that nature's rights are respected and protected (5.4.1.2, Visions of a good quality of life) (Te Urewera Act, ss. 16-17). All persons exercising powers under the Te Urewera Act "must act so that, as far as possible,

(a) Te Urewera is preserved in its natural state:
(b) the indigenous ecological systems and biodiversity of Te Urewera are preserved, and introduced plants and animals are exterminated" (Te Urewera Act, s. 5)

New Zealand is also noteworthy for having changed its electoral system in 1992 from first-past-the-post to mixed-member proportional representation (5.4.2.4, Managing for resilience) (New Zealand Electoral Commission, 2014). Advantages of proportional representation include parliaments that fairly reflect the popular vote, embody diverse populations, and require a genuine majority of the votes to form a majority government. The Green Party has played a significant role in New Zealand politics since the shift to proportional representation, serving in several coalition governments and contributing to stronger environmental laws and policies (Bale & Bergman, 2006).

5.4.3.2 Initiating Transformation, before Political Will

The examples provided throughout the chapter largely illustrate the multifaceted progress that is possible given sufficient political will, which begs the question of how to initiate transformative change towards sustainable pathways in the absence of such political will. Even in the six cases above (5.4.3.1), surely the political opportunity was created in part by various actors intervening in creative ways to enable broad and focused public support (such reconstructions of historic political processes are beyond the scope of this assessment). One of the most empowering findings that emerge from the analysis of societal responses to nature and biodiversity degradation is that individual and local efforts might be scaled up to transformative change for sustainability, including as initiated by the private sector, civil society, and governments at all scales.

There are countless worthy initiatives addressing the aforementioned leverage points and levers in various ways. These efforts deserve to be commended, and they can scale up. But they can also be better aligned with our findings above (5.4.1, 5.4.2). For example, there is a great deal of attention to reforming investment and technological innovation for a low-carbon economy, but few efforts broaden beyond climate pollution to include comprehensive impacts on biodiversity and ecosystem services, as suggested above (5.4.1.6, 5.4.1.7). Addressing the leverage points obliquely or partially (e.g., only carbon) can be counterproductive, e.g., potentially incentivizing other kinds of impacts on nature.

Existing efforts can also be better integrated, so that the various efforts can together leverage sustainability rather than undercut each other. For example, efforts to change behaviours among producers or urban populations (5.4.1.3) can be designed also to support the involvement of Indigenous Peoples and Local Communities (rather than detracting or distracting from this; 5.4.1.5).

There are also three apparent gaps in current efforts. First is laying the groundwork for a broad-scale reform of subsidies and incentives, which have structural effects (5.4.2.1). Although there is recent progress with carbon pricing (Kossoy *et al.*, 2015), there are benefits to extending these efforts in several ways. These would include advocating for and ensuring that carbon prices permeate supply chains and cross-border trade (Fischer & Fox, 2012); extending beyond carbon to include water (Molle & Berkoff, 2007), land use or conversion, and other metrics of damage or threat to biodiversity and ecosystem services; and ensuring that incentive programs are designed to foster relational values, not just 'buy' behaviour change (Chan *et al.*, 2017a) (5.4.2.1). Moreover, across many nations, there is disproportionately little effort to take stock of and address the perverse ecological impacts of subsidies on production and consumption (5.4.2.1). Because of the opposition that often arises in response to such policy reform, however, in many contexts policy progress may rely upon first laying the groundwork by enabling the widespread expression and reinforcement of supporting values (5.4.1.3; see also final point).

Second, compared with environmental laws and policies, there is a dearth of attention to the structure and approach of governing institutions to ensure that they are adaptive, precautionary, and addressing the resilience of social-ecological systems (5.4.2.2, 5.4.2.3, 5.4.2.4). Multi-stakeholder non-governmental organizations—often around certification systems—offer some promise to leverage change within commodity sectors (e.g., palm oil, soy, cotton, and rubber), when power inequities are addressed (e.g., so that small-holders have a substantial voice). Such structural changes can be fundamental (e.g., Olsson *et al.*, 2008), and yet sometimes they can elicit a broader base of support or less focused opposition. Accordingly, they may present especially promising targets for advocacy and intervention, recognizing it may take persistent and prolonged engagement.

Finally, although there are many behaviour-change programs, these efforts generally encounter one of two major obstacles to fostering system transformation. Many campaigns appeal only to a small minority of self-identified environmentalists (Moisander, 2007), which can impede behaviour change among the broader public due to negative stereotypes and the narrow reach of social norms (Chan *et al.*, 2017b). Alternatively, broad systems of taxation or incentives often lack a broad base of support or conflict with existing attitudes and values, which can backfire due to widespread resentment and/or non-participation (Chan *et al.*, 2017a). The values and concerns of voting publics are often key impediments to and enablers of top-down change. Accordingly, we see a crucial opportunity in programs and approaches that seek to leverage widely held but latent values of responsibility into new social norms in environmental (and social-ecological) contexts, perhaps by empowering all people to act in accordance with those values—easily, enjoyably and inexpensively (5.4.1.3).

Thus, a key message of this chapter is the transformative potential of identifying the diverse relational values that people already hold (principles, preferences, and virtues about relationships involving nature) that are conducive to sustainability and engineering the structural and social changes that will allow the full expression and growth of those values. These values include diverse ideals of sufficiency at the centre of *notions of a good life* that don't entail runaway *consumption* (5.4.1.1, 5.4.1.2); diverse values of responsibility are central to enabling new *social norms and action* for sustainability (5.4.1.3) including through *incentives* and regimes of *innovation, technology and investment* that align with those values (5.4.2.1, 5.4.1.7); recognition of local values consistent with conservation is an important reason to *involve Indigenous Peoples and Local Communities in conservation* (5.4.1.5); *education* is key for appreciating diverse values, which are embodied in the diverse *knowledge systems* that deserve to be maintained (5.4.1.8).

5.5 CONCLUDING REMARKS

Options for sustainable pathways abound, and our analysis suggests that they are within reach, if a diverse set of actors take action to enable them. These pathways entail addressing knotty nexuses of competing human needs, including food, biodiversity conservation, freshwater, oceans and coasts, cities, and energy. Both the actions and the pathways are clearly context-specific, with a need to tailor to regional and local circumstances via inclusive participation, but there are also key commonalities across regions and nexus points.

Across and beyond the six foci, one commonality is a diverse set of 'levers' and leverage points within which outcomes for nature, its contributions to people, and human drivers can be accomplished with strategic change. Many of these levers and leverage points have been identified elsewhere, but none have been employed widely and fully. This limited uptake is, of course, due to a variety of obstacles (chapter 6), but none of these are insurmountable with time, effort, resources, coordination, creativity, strategy, and persistence.

While all levers and leverage points are important, not all need be addressed by any one project, policy, or actor. But given strong interactions (e.g., synergies and trade-offs) between various levers and leverage points, we have described how engaging several together may be easier and more effective than addressing them piecemeal (5.4.3). For example, subsidy reform (5.4.2.1) and improved policies for innovation and technology (5.4.1.7) are excellent steps alone but often ineffectual in the presence of systemic corruption or weak rule of law (5.4.2.5). Similarly, enlisting values to encourage widespread conservation (5.4.1.3) and involving Indigenous Peoples and Local Communities in landscape management (5.4.1.5) are much needed, but they cannot yield long-term achievement of nature-based goals without also reining in overconsumption (5.4.1.2), likely by engaging appropriate visions of a good quality of life (5.4.1.1).

A key constituent and outcome of the transformational pathways suggested to achieve the SDGs is the emergence of a global sustainable economy, underpinned by a networked set of sustainable societies. The SDGs and many other agreements and collective efforts are inspiring societies and nations to envision a world in which innovation, new technology, and environmentally responsible consumption evolve towards eliminating environmental impacts, diminishing inequalities, and improving human well-being. Such a world would be enabled by diverse people and organizations engaging voluntarily in conservation and restoration, where all people are accorded inherent rights to nature and celebrated for their crucial roles in maintaining that nature for distant people, future generations, and nature itself.

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Chapter 6.

OPTIONS FOR DECISION MAKERS

IPBES GLOBAL ASSESSMENT REPORT ON BIODIVERSITY AND ECOSYSTEM SERVICES
CHAPTER 6. OPTIONS FOR DECISION MAKERS

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CHAPTER **6**

OPTIONS FOR DECISION MAKERS

EXECUTIVE SUMMARY

1 **The Sustainable Development Goals and the 2050 Vision for Biodiversity cannot be achieved without transformative change, the conditions for which can be put in place now *(well established)* {6.2; chapters 2, 3, 5}.** In the short term (before 2030), all decision makers can contribute to the sustainability transformation, including through the rapid and improved deployment of existing policy instruments and new initiatives that more effectively enlist individual and collective action for transformative change, and the reform and removal of harmful existing policies and subsidies *(well established)*. Additional measures are necessary to enable transformative change in the long term (up to 2050) to address the indirect drivers that are the root causes of nature deterioration (*well established*), including changes in social, economic and technological structures within and across nations {6.2, 6.3, 6.4}.

2 **Transformative change needs innovative approaches to governance. Such transformative governance can incorporate different existing approaches, such as integrative, inclusive, informed and adaptive governance. While these governance approaches have been extensively practiced and studied separately, their combined contribution to enabling transformative change has not yet been thoroughly explored (*established but incomplete*) {6.2}.** Integrative approaches, such as mainstreaming across government sectors, are focused on the relationships between sectors and policies and help to ensure policy coherence and effectiveness (*well established*). Inclusive approaches help to reflect a plurality of values and ensure equity (*established but incomplete*), including through equitable sharing of benefits arising from their use and rights-based approaches (*established but incomplete*). Informed governance entails novel strategies for knowledge production and co-production that are inclusive of diverse values and knowledge systems (*established but incomplete*). Adaptive approaches, including learning from experience, monitoring and feedback loops, contribute to preparing for and managing the inevitable uncertainties and complexities associated with social and environmental changes (*established but incomplete*) {6.2}.

3 **Empowering all actors can promote sustainability and ensure inclusiveness and equity.** Current policies and actions for nature, nature's contributions to people (NCP) and good quality of life (GQL) often privilege elite actors and their value systems, which hampers their legitimacy and effectiveness *(well established)*. Empowerment strategies can be implemented by governments and civil society groups, and include education and information instruments, but also redistribution of power and rights so that all can assume responsibility and control over their lives and futures *(well established)*. Existing approaches such as co-management and community-based natural resource management can be effective in ensuring the equal distribution of the costs and benefits of conservation and reconciling different interests and values, provided that they recognize and address trade-offs and uneven power relations *(well established)*. Inclusiveness and equity will imply recognizing the inevitability of hard choices, costs and common responsibilities *(well established)* {6.2; 6.3; 6.4}.

4 **Effective decision making for transformative change uses a mix of instruments and tools, and bridges across different sectors, levels and scales *(established but incomplete).*** Since no single instrument or tool is sufficient *(well established)*, policy mixes need to be carefully tailored to – together – effectively address all direct and indirect drivers of nature deterioration **(Table 6.1)**. Sectoral policies and measures can be effective in particular contexts, but often fail to account for indirect, distant and cumulative impacts, which can have adverse effects, including exacerbating inequalities *(well established).* Cross-sectoral approaches, including landscape approaches, integrated watershed and coastal zone management, marine spatial planning, bioregional scale planning for energy and new urban planning paradigms, offer opportunities to reconcile multiple interests, values and forms of resource use, provided that these cross-sectoral approaches recognize trade-offs and uneven power relations between stakeholders (*established but incomplete*) {6.3; 6.4}.

5 **Since the effectiveness of alternative actions and policies depends on the decision context, there are no generic recipes for success *(established but***

incomplete). All decision makers can contribute to enhancing the effectiveness of instruments in specific contexts over time through informed and adaptive governance approaches. The comprehensive review of the application of policy instruments presented in this chapter indicates that the implementation of many existing instruments (e.g. protected areas) can be further enhanced, while on the other hand the effectiveness and application of other instruments (e.g. information campaigns for consumers or agricultural certification schemes) requires more research. Since the effectiveness of many instruments for the conservation of nature and its contributions in different contexts is currently unknown, more research and appropriate monitoring is needed {6.3; 6.4}.

6 **Decision makers have a range of options and tools for improving the sustainability of economic and financial systems *(well established)* {6.4}. Achieving a sustainable economy involves making fundamental reforms to economic and financial systems and tackling poverty and inequality as vital parts of sustainability** *(well established)* {6.4}. Governments could reform subsidies and taxes to support nature and its contributions to people, removing perverse incentives, and instead promoting diverse instruments such as payments linked to social and environmental metrics, as appropriate *(established but incomplete)* {6.4.1}. Trade agreements and derivatives markets could be reformed to promote equity and prevent deterioration of nature, although there are uncertainties associated with implementation (*established but incomplete*) {6.4.4}. To address overconsumption, voluntary measures can be more effective when combined with additional incentives and regulation, including promotion of circular economies and sustainable production models *(well established)* {6.4.2; 6.4.3}. Although market-based policy instruments such as payments for ecosystem services, voluntary certification and biodiversity offsetting have increased in use, their effectiveness is mixed, and they are often contested; thus, they should be designed and applied carefully to avoid perverse effects in context (*established but incomplete*) {6.3.2.2; 6.3.2.5; 6.3.6.3}. Alternative models and measures of economic welfare (such as inclusive wealth accounting, natural capital accounting and degrowth models) are increasingly considered as possible approaches to balancing economic growth and conservation of nature and its contributions and recognizing trade-offs, value pluralism and long-term goals *(established but incomplete)* {6.4.5}.

7 **Recognizing the knowledge, innovations and practices, institutions and values of Indigenous Peoples and Local Communities and their inclusion and participation in environmental governance often enhances their quality of life, as well as nature conservation, restoration and sustainable use, which is relevant to broader society *(well established)* {6.2.4.4}. Governance, including customary institutions and management systems, and co-management regimes involving Indigenous Peoples and Local Communities, can be an effective way to safeguard nature and its contributions to people, incorporating locally attuned management systems and indigenous and local knowledge.** The positive contributions of Indigenous Peoples and Local Communities to sustainability can be facilitated through national recognition for land tenure, access and resource rights in accordance with national legislation{6.3.2.3}, the application of free, prior and informed consent {6.3.6}, increasing participation in resource management decision-making (including through capacity development and financial support) {6.2.4.4, 6.3.4}, and improved collaboration, fair and equitable sharing of benefits arising from the use, and co-management arrangements with Indigenous Peoples and Local Communities *(well established)* {6.2.4, 6.3.2.3}.

8 **Multi-functional landscapes consisting of mixed land systems that include intensive and extensive forms of land use are critical for food security and rural livelihoods, generate a diversity of nature's contributions to people, and can harbour considerable biodiversity (*well-established)* {6.3.2}.** At the same time, these landscapes are the space where the largest conflicts with nature take place *(well established).* Policy mixes harmonized across sectors, levels of governance and jurisdictions can account for ecological and social differences across and beyond the landscape, build on existing forms of knowledge and governance and address trade-offs between tangible and non-tangible benefits in a transparent and equitable manner *(established but incomplete).* Options for the private sector – especially local land managers – include diversified land uses and crops, including agroforestry practices, crop rotations, maintenance of semi-natural habitats, soil conservation practices and habitat restoration activities *(well established)*. Options that require the engagement of all actors related to the landscape (e.g., regional governments, producers, neighboring urban inhabitants, protected area authorities) include context-sensitive combinations of participatory approaches to resolve trade-offs and conflicts among objectives, certification schemes for landscape products, direct payments such agri-environmental schemes and PES, research on ecological intensification practices, technical outreach and information campaigns *(established but incomplete)* {6.3.2}.

9 **Feeding the world in a sustainable manner, especially in the context of climate change and population growth, entails food systems that ensure adaptive capacity, minimize environmental impacts, eliminate hunger, and contribute to human health and animal welfare *(established but incomplete)* {6.3.2.1}.** Ensuring the adaptive capacity of food production

incorporates measures that conserve the diversity of genes, varieties, cultivars, breeds, landraces and species. Essentially, this refers to further improvement and harmonization of present global mechanisms of genetic material transfers (e.g., the Nagoya Protocol, the International Treaty on Plant Genetic Resources for Food and Agriculture and the International Convention for the Protection of New Varieties of Plants*) (well established).* Options for the private sector – especially food producers – include expanding and enhancing sustainable intensification, engaging in ecological intensification and sustainable use of multi-functional landscapes, increasing focus on climate-resilient agriculture, and improving food distribution *(established but incomplete).* Options for governments at the international and national levels include regulating commodity chains, managing large-scale land acquisitions, and expanding food market transparency and price stability. Options that address and engage other actors in food systems (including the public sector, civil society and consumers, grassroot movements) include participatory on-farm research, promotion of low-impact and healthy diets and localization of food systems. Such options could help reduce food waste, overconsumption, and demand for animal products from unsustainable production, which could have synergistic benefits for human health *(established but incomplete)* {6.3.2.1}.

10 Sustainable forest management can be better achieved through promoting multifunctional, multi-use, multi-stakeholder and improving community-based approaches to forest governance and management (*well established*) {6.3.2.2}. National and subnational governments can further promote and strengthen community-based management and governance, including customary institutions and management systems, and co-management regimes involving Indigenous Peoples and Local Communities with due recognition of their knowledge and rights who manage almost one third of the forests in the Global South; and improve the conservation and sustainable use of (old-growth) forests through a combination of measures and practices, including protected and other conservation areas; sustainable management and reduced impact logging, forest certification, PES and reducing emissions from deforestation and forest degradation (REDD+); supporting reforestation and forest restoration; transparent monitoring; and addressing illegal logging *(established but incomplete).* International agencies can technically and financially support governments and other stakeholders in achieving the above, including through effective implementation of multilateral environmental agreements (MEAs) and other relevant international agreements *(well established).* Decision makers at all levels can also improve forest governance by recognizing different value systems while formulating forest policies and making management decisions and adopting informed and adaptive decision-making practices *(established but incomplete)* {6.2.4.1; 6.3.2.2; 6.3.2.3}.

11 Expanding and effectively managing the current network of protected areas, including terrestrial, freshwater and marine areas, is important for safeguarding biodiversity (*well established*), particularly in the context of climate change. Conservation outcomes also depend on adaptive governance, strong societal engagement, effective and equitable benefit-sharing mechanisms, sustained funding, and monitoring and enforcement of rules *(well established)* {6.3.2.3}. Protected areas support nature, deliver NCP and contribute to good quality life *(well established)*. National Governments play a central role in supporting primary research and effective conservation and sustainable use of multi-functional landscape and seascape. The latter include planning ecologically representative networks of interconnected protected areas to cover key biodiversity areas and managing trade-offs between societal objectives that represent diverse worldviews and multiple values of nature *(established but incomplete)*. Governance diversity, tailored to the local conditions, includes co-management schemes, local empowerment, and formal recognition of IPLCs rights over their territories *(well established).* Large-scale, proactive landscape planning, including transboundary conservation planning, helps prioritize land uses that balance nature, NCP and GQL *(well established)*. Implementation beyond protected areas includes combating wildlife and timber trafficking through effective enforcement and ensuring the legality and sustainability of trade in wildlife. Such actions include prioritizing wildlife trafficking in criminal justice systems, using community-based social marketing to reduce demand and implementing strong measures to combat corruption at all levels (*established but incomplete)* {6.3.2.3}.

12 Managing coastal and near-shore ocean management for sustainable and resilient futures, in the face of economic pressures and climate change, entails applying policy mixes, including integrated coastal planning and restoration, designation and expansion of Marine Protected Areas, control of plastic and other pollution, and reform of fishery subsidy strategies (*established but incomplete*) {6.3.3.3}. Marine protected areas (MPAs) have demonstrated success in both biodiversity conservation and improved local quality of life when managed effectively. MPAs can be further expanded through larger or more interconnected protected areas or new protected areas in currently under-represented regions and key biodiversity areas *(established but incomplete)* {6.3.3.3.1}. The fishing industry, a major source of aquatic biodiversity losses, can be supported by positive incentives and the reform and removal of harmful existing policies and subsidies to change current practices and remove derelict gear that threatens nature *(well established)* {6.3.3.3.2}. Improved surveillance and investment in scientific research are critical due to major pressures on coasts (including development, land reclamation and water pollution), implementing marine conservation outside protected areas, such as integrated coastal planning, is important for biodiversity conservation and sustainable use *(established but incomplete*) {6.3.3.3}. Other measures to expand multi-sectoral cooperation on coastal management include corporate social responsibility measures, standards for building and construction and eco-labelling (*well established*) {6.3.3.3.2, 6.3.3.3.5}. Additional tools could include economic instruments for financing conservation both non-market and market based, including for example payment for ecosystem services, biodiversity offset schemes, blue-carbon sequestration, cap-and-trade programs, green bonds and trust funds and new legal instruments {6.3.3.1.3}.

13 Governance for the oceans and high seas is currently marked by policy fragmentation leading to nature deterioration *(established but incomplete)* {6.3.3.1}. To sustain biodiversity and fisheries in the high seas, existing sectoral regulatory agencies such as shipping authorities and Regional Fisheries Management Organizations can increase the pace of mainstreaming nature into their policies *(well-established)* {6.3.3.2}. Based on the experience of regional fisheries management organisations, a strong science foundation for informed governance is essential for effective protection, although costly in terms of human resources and technology *(well established)* {6.3.3.2.2}. Cost-effectiveness can be achieved through sharing and integrating information systems across agencies and sectors (e.g., shipping, fishing, mining, and port agencies) and through collaboration between industry, governments and non-governmental organizations *(well established*) {6.3.3.1.1}. New legal instruments such as the proposed international legally binding instrument under the United Nations Convention on the Law of the Sea (UNCLOS) on the conservation and sustainable use of marine biodiversity of areas beyond national jurisdiction could accelerate national action to provide nature protection, particularly when combined with strengthened regional cooperation *(established but incomplete)* {6.3.3.3.1, 6.3.3.1.1}.

14 Inclusive water governance can promote informed decisions, facilitate stronger interaction between communities and conservation activities, and foster equity among water users (*well established*) {6.3.4}. Creating a space for stakeholder engagement and transparency in water conservation and transboundary water management can help to minimize environmental, economic and social conflicts as well as risks *(well established)* {6.3.4.3, 6.3.4.7}. Integrated freshwater management depends, *inter alia*, on recognizing the functional interdependencies between and among rural landscape management and urban demands, incorporating a regional view of the water cycle, understanding of conflicting interests for water uses, and assessing the opportunities for cooperation among users *(established but incomplete)* {6.3.4.1, 6.3.4.2, 6.3.4.6}. In the short term, collection and monitoring of data remains crucial to governments and private actors for water abstraction and management due to the interconnected nature of surface and groundwater (*well established)* {6.3.4.1}. With regard to watershed payment for ecosystem services programmes, their effectiveness and efficiency can be enhanced by acknowledging multiple values in their design, implementation and evaluation and setting up impact evaluation systems (*established but incomplete*) {6.3.4.4}. National regulatory frameworks, policy guidance, institutional arrangements, and water quality standards can set benchmarks for better performance and attract investment to improve water resources and conditions *(well established)* {6.3.4.5, 6.3.4.6}.

15 Nature-based solutions can be cost-effective for meeting the Sustainable Development Goals in cities, which are crucial for global sustainability *(established but incomplete)* {6.3.5}. Integrated urban planning can play a significant role in reducing the environmental impacts of cities and the transformation to sustainability *(well established)* {6.3.5.1, 6.3.5.3}. Nature-based approaches include safeguarding or retrofitting of green and blue infrastructure such as green spaces, water, and vegetation and tree cover into existing urban areas and in new settlements. They can contribute to flood protection, temperature regulation, urban food production, recreation, cleaning of air and water, treating wastewater and the provision of energy, locally sourced food and the health benefits of interacting with nature. They can also enhance urban biodiversity, and they can provide cost effective solutions for local climate change adaptation and promoting low carbon cities *(well established)* {6.3.5.2}. Nature-based solutions and integrated planning also enable improved access to social services, such as sanitation and housing *(well established)* {6.3.5.4}.

16 Recognizing pluralistic values and diverse interests are key to mitigating the impacts, and enabling the sustainable management of energy, mining and infrastructure *(established but incomplete)* {6.3.6}. At all levels of governance, it is crucial to integrate sustainability criteria and internalize the impacts of bioenergy projects on nature *(established but incomplete)* {6.3.6.1}. Promoting innovative financing and ensuring compensation for environmental and social impacts of energy, mining and infrastructure projects are important measures in the sustainable energy transition and responsible mining *(established but incomplete)* {6.3.6.2, 6.3.6.3, 6.3.4.6}. Community-based management and respect for the rights of Indigenous Peoples and Local Communities to land and water has emerged as a way to ensure access to clean, reliable and affordable energy *(well established)* {6.3.6.4, 6.3.6.5}. Incentive programs and policies can also aim at reducing consumption, improving energy efficiency, and supporting community-based management and decentralized sustainable energy production {6.3.6.1,6.3.6.3, 6.3.6.4,6.3.6.5}.

Table 6 1 Main options for decision makers: Instruments that can be included in smart policy mixes.

Decision maker	Instruments that can be included in smart policy mixes within or across issues {Tables 6.3, 6.4, 6.5, 6.6,				
	Landscape approaches	Food	Forest	Conservation	
Intergovernmental organizations	Support and facilitate the development of transformative landscape governance networks together that develop policy mixes for sustainable use of multi-functional landscapes	Support and facilitate expansion and enhancement of sustainable intensification, ecological intensification and sustainable use of multi-functional landscapes Develop and harmonize agreements on genetic resources for agriculture	Improve reducing emissions from deforestation and forest degradation (REDD+) and payment for ecosystem services (PES) policies Address illegal logging and trade in illegal timber Facilitate enhanced forest monitoring	Facilitate expansion and improved management, functionality and connectivity of (transboundary) protected areas Address illegal wildlife trade Facilitate enhanced implementation of and coordination between multilateral environmental agreements Promote mainstreaming of biodiversity into other sectors Enable more financial support for conservation	
Governments (national, subnational, local)	Support, facilitate and engage in transformative landscape governance networks	Encourage dietary transitions and alternate consumption Support and facilitate expansion and enhancement of sustainable intensification; ecological intensification and sustainable use of multi-functional landscapes Facilitate localization of food systems and reduction of food waste Facilitate improvement certification standards Enable conservation of genetic resources for agriculture Manage large-scale land acquisitions	Improve the conservation of (old-growth) forests Enable expansion and improvement of community-based forest management and co-management Improve REDD+ and payment for ecosystem services policies Support reduced impact logging Promote improvement and implementation of certification Support reforestation and forest restoration Address illegal logging and trade in illegal timber Enhance forest monitoring	Expand and improve management, functionality and connectivity of (transboundary) protected areas Recognize management by IPLCs and Other Effective area-based Conservation Measures Strengthen enforcement and implementation of law and multilateral environmental agreements (MEA) and address corruption Enforce free, prior and informed consent (FPIC) and recognize IPLC rights Enhance approaches to invasive alien species (IAS) management Develop participatory approaches to restoration and link restoration to revitalizing indigenous and local knowledge Raise level of financial support for conservation Mainstream biodiversity into other sectors	
Non-Governmental Organizations	Engage in transformative landscape governance networks	Encourage dietary transitions and food waste reduction Engage in expansion and enhancement of sustainable intensification Engage in ecological intensification and sustainable use of multi-functional landscapes Improve certification standards	Engage in improvement of REDD+ and PES Engage in promoting and improving certification Engage in addressing illegal logging	Engage in expansion and improved management, functionality and connectivity of (transboundary) protected areas Support management by IPLCs and Other Effective area-based Conservation Measures Engage in addressing illegal wildlife trade	

6.7, 6.8}

Marine	Water	Cities	Energy	Sustainable economies
Implement global marine environmental agreements for shipping Promote comprehensive protection of biodiversity and ecosystem services of the High Seas Mobilize conservation funding	Address fragmentation of freshwater treaties Promote integrated water resource management and transboundary water management Strengthen rights- based approaches & freshwater standards	Promote sustainable urban planning Promote nature-based solutions and green infrastructure Promote increasing access to urban services	Develop standards for sustainable renewable energy projects Promote biodiversity inclusive environmental impact assessments	Promote sustainable production and consumption; circular economy models Reform trade system and World Trade Organization Promote reform of subsidies Promote reform of models of economic growth
Mainstream biodiversity conservation and promote ecosystem services Support shared and integrated ocean governance Promote stronger implementation of fisheries conservation measures Strengthen integrated management of coastal waters	Promote interlinkage among water-energy-food systems Develop integrated rights-based and participatory approach to water management Encourage stakeholder engagement Develop water-efficient agricultural practices Promote and facilitate nature-based solutions Restrict groundwater abstraction	Implement sustainable urban planning, including bioregional planning, biodiversity-friendly urban development, increasing green spaces, and creating space for urban agriculture Implement nature-based solutions and green infrastructure Reduce the impacts of cities by encouraging articulated density; discouraging car use and promoting public transportation; developing energy efficient building codes; and encouraging alternative business models Enhance access to urban services, including through sustainable urban water management, integrated sustainable solid waste management, incentive programs and participatory planning	Develop sustainable bioenergy strategies Strengthen and enforce biodiversity inclusive environmental impact assessment laws and guidelines Strengthen biodiversity compensation policies for development and infrastructure loss	Address over and under consumption through taxes on consumption, product labeling, discouraging overbuying, promotion of sharing economy Sustainable public procurement Reduce unsustainable production through taxes on resource consumption and degradation; promotion of circular economy models; capping of resource consumption; applying life cycle assessment Reform derivative and futures markets Reform subsidies by assessing impacts of all subsidies policies and long-term removal of all environmentally-unsound subsidies Application of alternative measures of economic welfare and Natural Capital Accounting; move towards steady state economics paradigm and degrowth agenda
Develop conservation programs to raise awareness on local ecosystems, species values and knowledge Engage stakeholders Contribute to global assessments and participate in the global standard setting Engage in developing and monitoring fishery certification schemes	Organize awareness raising activities Engage in nature-based solutions Engage in developing and monitoring water quality and abstraction related standards	Engage in sustainable urban planning Promote the reduction of the impacts of cities Engage in enhancing access to urban services	Participate in community led initiatives Engage in developing and monitoring bioenergy standards and schemes	Develop initiatives to discourage overbuying; engage in development of product labeling Promote circular economy Promote initiatives for transformation to sustainable economy

Decision maker	Instruments that can be included in smart policy mixes within or across issues {Tables 6.3, 6.4, 6.5, 6.6,				
	Landscape approaches	Food	Forest	Conservation	
Citizens, community groups, farmers	Engage in transformative landscape governance networks	Change to sustainable consumption (diet, reducing waste) Engage in localized food systems Engage in expansion and enhancement of sustainable intensification; ecological intensification and sustainable use of multi-functional landscapes Engage in conservation of genetic resources for agriculture	Engage in community-based forest management and co-management Change to sustainable consumption	Engage in conservation efforts	
Indigenous People and Local Communities	Engage in transformative landscape governance networks	Engage in conservation of genetic resources for agriculture	Engage in community-based forest management and co-management Engage in forest monitoring	Engage in management Engage in addressing illegal wildlife trade; sustainable wildlife management Engage in restoration and revitalization of indigenous and local knowledge	
Donor agencies	Support transformative landscape governance networks	Support reduction of food waste; localized food systems; sustainable intensification; ecological intensification	Support community-based forest management and co-management; improvement of REDD+ and PES policies; improvement and implementation certification; initiatives addressing illegal logging; enhanced forest monitoring	Support expansion and improved management, functionality and connectivity of (transboundary) PAs; management by IPLCs and Other Effective area-based Conservation Measures; addressing illegal wildlife trade Raise level of financial support for conservation	
Science and educational organizations	Engage in transformative landscape governance networks	Engage in expansion and enhancement of sustainable intensification and ecological intensification Engage in transformation food storage and delivery systems Facilitate conservation and sustainable use of genetic resources for agriculture	Support reduced impact logging Support improvement of certification Engage in enhancing forest monitoring	Analyze social and economic impacts of restoration Analyze conservation impacts of Official Development Assistance	
Corporate actors	Engage in transformative landscape governance networks	Contribute to expansion and enhancement of sustainable intensification Contribute to ecological intensification Transform food storage and delivery systems Improve certification standards Engage in conservation of genetic resources for agriculture	Implement reduced impact logging Engage in improvement and expansion of forest certification Address illegal logging and trade in illegal timber	Engage in addressing illegal wildlife trade Engage in restoration Raise level of financial support for conservation	

6.7, 6.8}

Marine	Water	Cities	Energy	Sustainable economies
Engage in policy decision making, remedial actions, and educational programs Engage in awareness campaigns to influence consumer behaviour and consumption	Participate in ecosystem restoration activities Engage in collaborative initiatives	Engage in sustainable urban planning Engage in development and maintenance of nature-based solutions and green infrastructure Change to sustainable consumption (reduced waste, increased public transport) Engage in initiatives to access to urban services	Actively engage in community led activities	Engage in reduced consumption movements and change towards sustainable consumption; local reuse or fix-up initiatives Support companies with sustainable production models
Engage in coastal management and MPA Collaborate in integrated management of marine resources	Support co-management regime for collaborative water management Engage, where appropriate, with payment for ecosystem services or other local water ecosystem services provisioning schemes	Engage in advocacy networks for sustainable cities	Participate in formulating sustainable bioenergy strategies Engage in the implementation of Free, Prior and Informed Consent	Engage in discussions over values in a sustainable economy and good life
Support funding sources in the High Sea that ensure conservation Ensure funding promotes sustainable fishing practices Promote innovative and longer term financing through market based mechanisms	Establish standards and guidelines that improve water quality and integrate social and environmental considerations	Support sustainable urban planning Support initiatives to enhance access to urban services	Promote innovative financing for sustainable infrastructure Establish sustainable bioenergy guidelines	Support initiatives to transform to sustainable economy Fund projects on use of alternative welfare measures
Promote mainstreaming climate change adaptation and mitigation into marine and coastal governance regimes	Promote awareness raising activities	Support sustainable urban planning, development of nature-based solutions and green infrastructure, reduction of the impact of cities and enhancing access to urban services	Promote awareness raising activities	Support circular economy; further include BES in life cycle assessment Research on environmental impacts of futures and derivatives Support reform of models of economic growth
Engage in CSR activities, certification and best practices in fisheries and aquaculture production methods Mobilize conservation funding for the oceans Take account of ecological functionality into coastal infrastructure	Engage in setting water quality and abstraction related standards Engage in water restoration schemes Promote sustainable investment in water projects Invest in clean and environmentally sound technology	Engage in sustainable urban planning Develop energy efficient buildings Engage in alternative business models Engage in partnerships and other initiatives to enhance access to urban services	Engage in setting sustainable bioenergy strategies Promote sustainable infrastructure practices Strengthen biodiversity compensation policies Promote innovative financing for sustainable infrastructure	Implement sustainable sourcing practices; design for sustainability; engage in development of product labeling; apply life cycle assessment; contribute to circular economy Engage in corporate social responsibility Engage in reform of models of economic growth

6.1 INTRODUCTION

In recent decades, the extent and scope of societal responses to environmental problems, including biodiversity decline, have been extensive and diverse. The outcomes, however, have been mixed across sectors and levels of governance, with limited success in reverting global trends and in addressing the root causes of degradation. Lessons and opportunities also abound, amid new challenges and scenarios. This chapter discusses opportunities and challenges for all decision makers to advance their efforts in meeting, synergistically, internationally agreed goals for sustainable development, biodiversity conservation, and climate change mitigation and adaptation. In doing so, the chapter builds on the analysis in the previous chapters, which have identified direct and indirect drivers of change, evaluated progress or lack of progress in achieving the Aichi Biodiversity Targets, the Sustainable Development Goals (SDGs), and several environmental conventions, and assessed plausible scenarios and possible pathways. Previous chapters of the present assessment show that, despite progress on various goals and targets and improvements in environmental indicators in many regions, species diversity, ecosystems functions and the contributions they provide to society continue to decline, further reinforcing both environmental and societal problems.

While progress can be made to achieve the Aichi Biodiversity Targets, the CBD 2050 Vision and the SDGs using current policies, practices and technologies, and within current national and international governance structures, these are not enough to address current and projected trends. It has become widely recognized that transformative change is needed to fully realize these ambitions (CBD/SBSTTA/21/5, 12 October 2017; CBD/SBSTTA/21/2, 15 September 2017). In fact, the adoption of the SDG shows that the international community has committed itself to such transformative change: "*We are determined to take the bold and transformative steps which are urgently needed to shift the world on to a sustainable and resilient path*" (UNGA, 2015).

Transformative change can be defined as a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values (IPBES, 2018a; IPCC, 2018). Such fundamental, structural change is called for, since current structures often inhibit sustainable development, and actually represent the indirect drivers of biodiversity loss (Díaz *et al.,* 2015) (See Section 6.2. below). Transformative change is thus meant to simultaneously and progressively address these indirect drivers. The character and trajectories of this transformation will be different in different contexts, with challenges and needs differing, among others, in developing and developed countries.

Transformative change is facilitated by innovative governance approaches that incorporate existing approaches such as integrative, inclusive, informed and adaptive governance. While such approaches have been extensively practiced and studied separately, it is increasingly recognized that together they can contribute to transformative change (see section 6.2). The concept of governance refers to the formal and informal (and public and private) rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards positive outcomes and away from harmful ones (adapted from Biermann *et al.,* 2010).

In response to the interconnected challenges of sustainable development, biodiversity conservation,

Table 6 2 **List of decision makers.**

	Decision maker
1	Global and regional (inter)governmental organizations (UN, MEA secretariats etc.)
2	National, sub-national and local governments
3	Private sector
4	Civil society, including: • Citizens (households, consumers), community groups, farmers • NGOs (e.g., environmental, human development, consumer, trade unions)
5	Indigenous Peoples and Local Communities (IPLCs)
6	Donor agencies (public and private)
7	Science and educational organizations

and climate change identified in previous chapters, this chapter organizes its analysis on the options for decision makers around sustainability pathways in five domains: terrestrial landscapes (6.3.2), marine, coastal and fisheries (6.3.3); freshwater (6.3.4); cities (6.3.5); and energy and infrastructure (6.3.6). Finally, the chapter discusses approaches and conditions that enable transformation towards sustainable economies (6.4). Each of these major issues is considered in terms of short- and long-term options, and against possible obstacles for decision makers to enable transformative change. The chapter distinguishes different decision makers (see **Table 6.2**).

Our analysis of options implemented so far shows that, already in the short-term (before 2030), all decision makers can contribute to the transformation towards sustainability by applying existing policy instruments, which need to be enhanced and used together strategically in order to become transformative – in other words – not only address direct drivers, but especially indirect drivers. The existing instruments discussed in sections 6.3 and 6.4 can thus be further enhanced based on the lessons learned from earlier experiences with implementation. In the long-term (today-2050), transformative change will entail additional measures and governance approaches to change technological, economic, and social structures within and across nations.

Below, the chapter first discusses transformative change and transformative governance (section 6.2), after which the options for decision makers on the main issues are discussed (section 6.3). Section 6.4 highlights more generic options for a sustainable economy. The options in sections 6.3 and 6.4 are based on a systematic literature review of existing and emerging governance instruments and approaches. The review especially highlights lessons relevant to transformative governance, including cross-sectoral approaches and synergies and trade-offs between different societal goals, the impact of telecoupling of distant drivers, and lessons learned from incorporating diverse values, rights-based approaches and equity concerns in decision making and policy implementation (see section 6.2).

Due to the scope of the chapter's coverage and the extent of the literature review supporting it, the chapter includes a Supplementary Material document. A significant amount of the literature evidence supporting statements made in the chapter are presented there, thus we encourage the reader to consult Supplementary Material when cross-references are made in the main chapter.

6.2 TOWARDS TRANSFORMATIVE GOVERNANCE

As introduced in 6.1, transformative change can be defined as societal change in terms of technological, economic and social structures. It includes both personal and social transformation (Otsuki, 2015), and includes shifts in values and beliefs, and patterns of social behaviour (Chaffin *et al.,* 2016).

Transformative change has emerged in the policy discourse and is increasingly seen as both necessary and inevitable for biodiversity-related issues and sustainable development more broadly. The Convention on Biodiversity (CBD), European Environment Agency (EEA, 2015), OECD (OECD, 2015), World Bank (Evans & Davies, 2014), UN (UNEP, 2012), UNESCO (ISSC/UNESCO, 2013), European Union, national governments and the German Advisory Council on Global Change (WBGU, 2011), for example, have over the past years launched reports and policy programs in support of sustainability transformations or transitions. This attention is based upon the increasing understanding of the persistency of the complex sustainability challenges we face: in spite of high ambitions, policy commitments, large-scale investments in innovation and voluntary actions, our economies are still developing along unsustainable pathways pushing ecological boundaries (Rockstrom *et al.,* 2009; Future Earth, 2014). To escape this path-dependency it is increasingly clear that structural, systemic change is necessary, and continuing along current trajectories increases the likelihood of disruptions, shocks and undesired systemic change.

This process of nonlinear systemic change in complex societal systems has become the object of research especially since the late 1990s under the headers of 'transformation' (Feola, 2015; Olsson *et al.,* 2014; Folke *et al.,* 2010; Moore *et al.,* 2014) and 'transition' (Geels, 2002; Grin *et al.,* 2010; Markard *et al.,* 2012; Rotmans *et al.,* 2001; van den Bergh *et al.,* 2011; Turnheim *et al.,* 2015). While having different disciplinary origins (Hölscher *et al.,* 2018), both terms are increasingly used in a similar way referring to a particular type of change, namely nonlinear and systemic shifts from one dynamic equilibrium to another (Patterson *et al.,* 2016). A range of different scientific disciplines has studied underlying patterns and mechanisms of such transformation. Prominent fields of research include resilience, sustainability transition, innovation studies and social innovation research. While these debates have often remained rather a-political, a more critical perspective is emerging (see e.g. Blythe *et al.,* 2018; Chaffin *et al.,* 2016; Lawhon & Murphy, 2012; Meadowcroft, 2009; Scoones *et al.,* 2015) that incorporates politics, power, legitimacy and equity issues, recognizing that transformations include the making of "hard choices" by decision makers (Meadowcroft, 2009).

Governing transformative change, or *transformative governance,* can be defined as "an approach to environmental governance that has the capacity to respond to, manage, and trigger regime shifts in coupled socio-ecological systems at multiple scales" (Chaffin *et al.,* 2016). Transformative governance is deliberate (Chaffin *et al.,* 2016), and inherently political (Blythe *et al.,* 2018), since the desired direction of the transformation is negotiated and contested, and power relations will change because of the transformation (Chaffin *et al.,* 2016). Current vested interests (including in certain technologies) are thus expected to inhibit, challenge, slow down or downsize transformative change, among others through "lock-ins" (see e.g., Blythe *et al.,* 2018; Chaffin *et al.,* 2016; Meadowcroft, 2009). The debate on the related term "transition management" (Rotmans & Loorbach, 2010) points to the importance of (facilitating) emergent and co-evolutionary changes in cultures, structures and practices that challenge incumbent 'regimes' (Frantzeskaki *et al.,* 2017). This in itself requires forms of governance that complement more institutionalized, consensus-based and incremental policies by facilitating transformative actor-networks, back-casting processes, strategic experimentation and reflexive learning.

Transformative governance often needs a 'policy' or 'governance' mix aimed at navigating transformations (Kivimaa & Kern, 2016; Loorbach, 2014; Berkes *et al.,* 2008). In such a mix, instruments that facilitate the build-up of alternatives, the gradual change of institutional structures and the managed phase-out of undesirable elements need to be combined, dynamically based on a systemic understanding of the present transition dynamics (Loorbach *et al.,* 2017). How this is operationalized depends on the type of organization and level of operation and the types of (transformative) capacities, instruments and methods available (Wolfram, 2017; Fischer & Newig, 2016; Patterson *et al.,* 2016). Through co-creative multi-actor processes (Avelino & Wittmayer, 2015; Brown *et al.,* 2013) of seeking joint understandings of collective transition contexts and formulating shared desired future directions, different actors can align long-term agendas and more strategically use and implement short-term actions to guide and direct emerging transitions towards sustainable futures.

Transformative change thus needs innovative approaches to governance. Such transformative governance can incorporate different existing approaches, which we group into four domains, namely integrative, inclusive, informed and adaptive governance. While these approaches have been extensively practiced and studied separately, their combined contribution to enabling transformative change has not yet been thoroughly explored.

Transformative governance is: 1) *integrative,* since the change is related to and influenced by changes elsewhere (at other scales, locations, on other issues) (see e.g., Chaffin *et al.,* 2016; Karki, 2017; Reyers *et al.,* 2018; Wagner & Wilhelmer, 2017); 2) *informed*, based on different and credible knowledge systems (Blythe *et al.,* 2018; Chaffin *et al.,* 2016; Couvet & Prevot, 2015); 3) *adaptive,* based on learning, experimentation, reflexivity, monitoring and feedback (Colloff *et al.,* 2017; Chaffin *et al.,* 2016; Laakso *et al.,* 2017; Meadowcroft, 2009; Otsuki, 2015; Rijke *et al.,* 2013; Wagner & Wilhelmer, 2017); and finally 4) *inclusive* since transformative change per definition includes different types of actors, interests and values, and needs to address issues of social justice (Chaffin *et al.,* 2016; Otsuki, 2015; Blythe *et al.,* 2018; Li & Kampmann, 2017; Meadowcroft, 2009; Thomalla *et al.,* 2018; Wolfram, 2016). Below we elaborate on each of these four approaches to governance (not presented in order of importance).

6.2.1 Integrative governance: ensuring policy coherence and effectiveness

Since the middle of the 20th century, hundreds of multilateral environmental agreements, governmental policies and (public-) private initiatives have been developed, many of which are focused on, or relevant for, biodiversity. Moreover, different economic and policy sectors (including biodiversity conservation, climate change, agriculture, and mining) are often governed in silos at all levels of governance. This raises questions per level of governance and across levels of governance on *synergies and trade-offs* between different societal goals (see e.g., Mauerhofer & Essl, 2018). This is especially important for transformative change – the SDG cannot all be achieved simultaneously if they are not approached in an integrative manner – as recognized by the UN, which have stated that the goals and their targets are "integrated in indivisible" (UNGA, 2015).

This fragmentation and complexity of the governance for sustainable development are well recognized among scholars (see e.g., Alter & Meunier, 2009; Bogdanor, 2005; Rayner *et al.,* 2010; Tamanaha, 2008; Young, 1996), and policy makers are actively trying to enhance synergies and address trade-offs. The CBD, for example, promotes mainstreaming of biodiversity concerns into sectors impacting biodiversity, such as agriculture, forestry, fisheries, and tourism (UNEP/CBD/COP/13/24).

Integrative governance defined and the theories and practices focused on the relationships between governance instruments or systems (Visseren-Hamakers, 2015; 2018), addresses these challenges of incoherence in sustainability governance. The literature suggests various options for integrative governance, including:

- Integrated management (Born & Sonzogni, 1995), landscape governance and approaches (Buizer *et al.*, 2015; Görg, 2007; Sayer *et al.*, 2013), the nexus approach (Benson *et al.*, 2015; Rasul & Sharma, 2016), multilevel governance (Hooghe & Marks, 2003; Marks *et al.*, 1996), and telecoupling (Liu *et al.*, 2013), which bring together (or highlight the relationships between) different sectors, policies or levels of governance in trying to enhance coherence;

- (Environmental) policy integration (Jordan & Lenschow, 2010; Persson & Runhaar, 2018) and mainstreaming (Karlsson-Vinkhuyzen *et al.*, 2017; Kok and de Coninck, 2007), which aim to strengthen attention for environmental issues in other sectors;

- Interaction management (Oberthür, 2016), metagovernance, and orchestration (Abbott & Snidal, 2010; Kooiman & Jentoft, 2009), which aim to improve the relationships between (groups of) governance instruments; and

- Smart regulation and policy mixes (Gunningham and Grabosky, 1998; Mees *et al.*, 2014), which combine different instruments to be more effective together.

Additional concepts used to discuss and study integrative governance include interorganizational relations (see e.g., Schmidt & Kochan, 1977), legal pluralism (Griffiths 1986; Merry, 1988), polycentric governance (Ostrom, 2010), regime complexity and fragmentation (Biermann *et al.,* 2009; Fischer-Lescano & Teubner, 2003), coordination (Peters, 1998), coherence (Jones, 2002), institutional interplay or interaction (Oberthür and Gehring, 2006), governance architectures and systems (Biermann *et al.,* 2009), regime complexes (Abbott, 2012; Raustiala & Victor, 2004), and governance of complex systems (Young, 2017) (see Visseren-Hamakers, 2015, 2018). See **Box 6.1** for an example of Integrative Governance.

6.2.2 Informed governance: based on legitimate and credible knowledge

Traditionally, biodiversity governance has relied on natural science tools including red lists, monitoring and indicator frameworks, and models and scenarios to characterize, assess and project ecological values such as productivity, species diversity, or threatenedness. In addition, multidisciplinary tools containing knowledge and information about ecosystems, social systems, and economics, such as cost-benefit analysis, sustainability indicators, or integrated assessments are widely used and considered valuable for their ability to offer an integrated perspective (Ness *et al.,* 2007). Increasingly, these information tools and systems focus on the measurement, modeling and assessment of natural capital and ecosystem services (Turnhout *et al.,* 2013; McElwee, 2017).

These information tools and systems have several challenges and limitations. These include technical challenges such as standardization, data quality and availability, and interoperability and commensurability of data (Bohringer & Jochem, 2007; Kumar Singh *et al.,* 2009). More important is that they are mostly not fit for purpose to inform transformative governance. One reason is that they often focus exclusively on environmental dimensions and are insufficiently inclusive of diverse values (Turnhout *et al.,* 2013; 2018; Gupta *et al.,* 2012; Elgert, 2010). For example, biodiversity and ecosystem services models and assessments often use causal and mechanistic frameworks, such as the DPSIR (Drivers, Pressures, States, Impacts, Responses) approach, which are limited in their ability to account for both complex

Box 6 1 Example of Integrative Governance – CCAMLR.

The Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR) manages the currently active fisheries in the Antarctic Treaty System area (Patagonian toothfish (Dissostichus eleginoides), Antarctic toothfish (Dissostichus mawsoni), mackerel icefish (Champsocephalus gunnari) and Antarctic krill (Euphausia superba)). The commission exemplifies integrative governance since it uses a precautionary ecosystem-based approach that considers not just the commercial fish species but also the wider ecosystem, and because its management objectives balance conservation goals with the rational use of living resources, while safeguarding ecological relationships. It does so by using clear decision rules to agree on catch limits in each fishery. It also relies on detailed data from the fisheries and fishery surveys, and the CCAMLR Scheme of International Scientific Observation (https://www.ccamlr.org/en/science/ccamlr-scheme-international-scientific-observation) to monitor CCAMLR fisheries and to forecast fishery closures. Members implement compliance systems that include vessel licensing, satellite monitoring of vessel movements and transshipments, together with measures to specifically address the threat of illegal, unregulated and unreported (IUU) fishing. The CCAMLR conservation measures are generally seen to be efficiently implemented and represent a leading example of an agreement between over 50 States that has been effective in conserving the living resources of a significant part of the world's ocean.

causal pathways and societal factors such as institutions and values affecting them (Svarstadt *et al.,* 2008; Breslow, 2015). Equally, the usefulness of indicator and monitoring systems is hindered by their technical and specialized nature and by the way in which they prioritize specific values over others (Turnhout, 2009; Merry, 2011).

Transformative governance calls for expanding existing information systems and tools to include indicators and parameters to assess the integrative, informed, adaptive and inclusive nature of governance processes, policies and interventions as well as their intended and unintended effects on Nature, NCP and GQL. An interesting initiative in this respect is Conservation Evidence, which aims to improve conservation practice by collating, reviewing, assessing and summarizing all available evidence on the effectiveness of conservation interventions (Sutherland *et al.,* 2004, 2014, 2017). It is conceived to be a free, open-access and authoritative resource designed to support informed decisions about how to maintain and restore global biodiversity, thereby combatting the phenomenon of evidence complacency, where evidence is not used in conservation decision-making (Dicks *et al.,* 2014; Cook *et al.,* 2017; Sutherland & Wordley, 2017).

Informing transformative governance also requires reconsideration of the relationship between knowledge and decision-making. Scientific expertise is not in all cases required for effective and legitimate action, and the relationship between knowledge and decision-making is not straightforward or self-evident (Dessai *et al.,* 2009; Kolinjivadi *et al.,* 2017; Wesselink *et al.,* 2013. Dilling and Lemos, 2011, Sutherland *et al.,* 2004; Matzek *et al.,* 2014; Pullin *et al.,* 2014). This means that existing information systems and tools will need to be adapted to produce knowledge that is inclusive of multiple values and forms of scientific and non-scientific knowledge, including indigenous and local knowledge (ILK), and that is credible, legitimate and salient for all relevant stake- and knowledge-holders (Cash *et al.,* 2003; Robertson & Hull, 2001; Mauser *et al.,* 2013; Sterling *et al.,* 2017).

A crucial element in the production of legitimate and credible information is the facilitation of dialogue and learning (Lemos & Moorehouse, 2005; Breslow, 2015; Kok *et al.,* 2017; Peterson *et al.,* 2003; Turnhout *et al.,* 2007; Voinov & Bousquet, 2010). Literature on transdisciplinarity and coproduction offers a variety of tools and methods that can be used by governments, NGOs but also in bottom-up processes, to organize processes of participatory knowledge production that are able to bridge practical, scientific and technical knowledge, as well as ILK (Tengö *et al.,* 2014, 2017; Clark *et al.,* 2016). Experiences with participatory modeling and scenario planning have shown amongst others that participants were better able to grapple with complexity and uncertainty and that scenarios developed on the basis of input from stakeholders were helpful in identifying different interests and facilitated communication between stakeholders and governments (De Bruin *et al.,* 2017; Tress & Tress, 2003; Whyte *et al.,* 2014). Similarly, participatory – or citizen science – approaches involving stakeholders in the selection and monitoring of indicators cannot just contribute to the availability of relevant data, but also to engagement with nature and enhanced decision-making (Fraser *et al.,* 2006; Danielsen *et al.,* 2014). An interesting example has come from the availability of real-time satellite data, which are used by initiatives like Global Forest Watch to support national and sub-national governments, civil society and the private sector to engage in forest monitoring and conservation (FAO, 2015; GFW, 2017; Nepstad *et al.,* 2014; Assunção *et al.,* 2015).

However, the application of these inclusive and participatory approaches so far is limited (Brandt *et al.,* 2013), and their ability to produce positive outcomes for problem solving and stakeholder empowerment depends on the presence of an enabling institutional context (Armitage *et al.,* 2011) which is able to effectively address unequal power relations between stake- and knowledge-holders (Nadasdy, 2003; Dilling & Lemos, 2011).

6.2.3 Adaptive governance: to enable learning

Transformative change is in essence adaptive – it represents a learning process that needs regular opportunities for reflection on to what extent and how progress is being made, the main bottlenecks, and the best ways forward. Adaptive governance is a result of continuously learning about and adjusting responses to uncertainty, social conflicts and complexity in socio-ecological systems (Chaffin *et al.,* 2014; Dietz *et al.,* 2003; Walker *et al.,* 2004; Folke *et al.,* 2005; Folke, 2006; Karpouzoglou *et al.,* 2016).

Adaptive governance includes policy processes that highlight uncertainties, developing and evaluating different hypotheses around a set of outcomes and structuring actions to evaluate these ideas (Berkes *et al.,* 2003; Paul-Wost, 2009). Adaptive governance also focuses on enhancing the resilience of socio-ecological systems by increasing their capacity to adapt, and by recognizing the importance of learning in coping with change and uncertainty (Evans, 2012). Studies on adaptive governance advocate for an experimental approach to governing such as creating institutions that can experiment with different solutions and make adjustments in the process (Holling, 2004).

There are various challenges stated in the literature that can be seen as problematic in engaging with an adaptive governance paradigm. According to Gunderson (1999) these are inflexible social systems, ecological systems that lack resilience, and technological incapacity to design experimental and innovative approaches. Also, the question of scale is essential in adaptive governance mechanisms. The scale for adaptive governance responses needs to be adapted to the social and ecological nature of the problem with sufficient response flexibility within and between political boundaries (Cosens, 2010, 2013; Huitema *et al.,* 2009; Termeer *et al.,* 2010).

Adaptive management, through monitoring and feedback, is widely recognized as a management approach to ensure effective conservation (Walters, 1986). Several studies confirm the benefits of adaptive management and “learning through doing” (Kenward *et al.,* 2011; CBD, 2004; Bern Convention, 2007), and adaptive management has been applied in the ecosystem approach in order to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning (CBD, 2017). According to Lebel *et al.* (2006), adaptability is determined by two factors: (1) the absolute and relative forms of social, human, natural, manufactured, and financial capital, and (2) the system of institutions and governance. In order to enable a capacity to adapt, it is crucial to build trust and shared understanding between diverse stakeholders to motivate co-learning and adaptation. Accordingly, deliberation and polycentric governance are offered as tools for enabling adaptive governance.

Dietz *et al.* (2003) propose a general list of criteria necessary for adaptive governance: inclusive dialogue between resource users (analytic deliberation); complex, redundant, layered institutions (nesting); mixed institutional types (e.g., market- and state-based); and institutional designs that facilitate experimentation, learning, and preparation for change. See **Box 6.2** for an example of adaptive governance.

6.2.4 Inclusive governance: ensuring equity and participation

Inclusive governance refers to governance approaches through stakeholder engagement, including Indigenous Peoples and Local Communities, in decision-making processes. It is argued that inclusive governance improves the quality of decisions and secures legitimacy for the decisions that are taken. Reform of decision-making processes is also necessary to enhance accountability and legitimacy (Keohane, 2003; Bernstein, 2005; Biermann & Gupta, 2011; Evans, 2012).

Participatory mechanisms that introduce dialogue and negotiation can be used to discover varying and potentially competing values and knowledge systems and identify options for more equitable decisions and implementation of these decisions, and enable learning (see e.g. Innes and Booher, 1999). However, power asymmetries can also affect the manners in which values and knowledge systems are represented in such participatory platforms. Policymaking processes have often inadequately addressed minority groups or the interests and values of people who are actually or potentially affected, directly or indirectly. Procedural equity deals with power asymmetries that affect whose voice is heard and who has a say in access and control of nature (McDermott *et al.,* 2013).

Deliberative processes are widely recognized by practitioners as useful in many contexts, including urban planning, healthcare and water governance (Andersson & Ostrom, 2008; Neef, 2009; Parkins & Mitchell, 2005). Deliberative approaches are based on the assumption that competing interests and values can only be discovered, constructed and reflected in a dialogue with others (Rhodes, 1997; Dryzek, 2000; Kenter, 2016). Examples of deliberative institutions are citizen juries, consensus conferences and focus groups (Pelletier *et al.,* 1999; Smith, 2003; Lienhoop, 2015). Deliberative approaches are mostly applied at the local level but can also be used at other levels of governance Deliberative valuation can also capture the interests of future generations (Soma & Vatn, 2010; Stagl, 2006; Sagoff, 1998).

Deliberation is considered to be an integrating and bridging approach to valuation (Pascual *et al.,* 2017). Howarth and Wilson (2006) also describe the ways in which deliberative monetary valuation could contribute to social fairness. However, after deliberation it will nevertheless be essential that results be articulated in a metric that is comparable with conventional ecosystem service valuation techniques such as the contingent valuation method (Wilson & Howarth, 2002).

Box 6 2 **Example of Adaptive Governance – Urban green spaces and urban agriculture:**

Uses of vacant lots in urban areas are increasingly recognized as important sites for enhancing provisioning of nature’s contributions, such as water provisioning or climate regulation, and can also be used for food provisioning through urban agriculture. Adaptive governance principles have been realized in several “land bank” systems in the USA, such as in Cleveland, which join public and private organizations to purchase or reclaim parcels and then manage them adaptively for multiple objectives. Such strategies include plans to increase connectivity between lots and incorporate community involvement in lot management (Green *et al.,* 2016).

Inclusive governance to enhance transformative change thus needs to consider the importance of including diverse value systems, rights-holders, genders and IPLCs. These are discussed in more detail below (see **Box. 6.3** for an example of inclusive governance).

6.2.4.1 Value Systems

Decisions – made at the individual or institutional level and at different scales – are necessarily embedded in a given value system, historically rooted in the socio-cultural context and power relations; yet, such value systems may not be explicitly reflected upon (Barton *et al.,* 2018; Berbés-Blázquez *et al.,* 2016). Depending on whether a unidimensional or a more diverse (value pluralism) lens is applied by the decision maker, policy objectives, as well as policy instruments will be determined differently through formal and informal institutions (Pascual *et al.,* 2017; also see Chapter 1). Legal, economic and socio-cultural instruments currently regulating the use of nature and its contributions usually fail to address plural and multiple values of nature, instead they focus on unidimensional values (Chan *et al.,* 2016; Kolinjivadi *et al.,* 2017; Tallis *et al.,* 2014; Spangenberg & Settele, 2016) (See Supplementary Materials 6.1.1 for a discussion on market-based instruments). Additionally, they often have unintended consequences, such as motivational crowding[1] (Rode *et al.,* 2015; Vatn, 2010; Vatn *et al.,* 2014), trade-offs and conflicts (Kovács *et al.,* 2015; Turkelboom *et al.,* 2018, Whittaker *et al.,* 2018), or impacts on justice and power relations (Berbés-Blázquez *et al.,* 2016; Pascual & Howe, 2018; Sikor, 2014). Being transparent about underlying value systems and accommodating plural values and knowledge forms in decision-making widens collaboration and creates more inclusive institutional arrangements (Ainscough *et al.,* 2018; O'Neill & Spash, 2000). However, decision making in this context might be technically challenging (Dendoncker *et al.,* 2018; Phelps *et al.,* 2017; Primmer *et al.,* 2018), because value articulation needs to be equitable; conflicts often emerge between stakeholders holding different values; and plural and incommensurable values are difficult to operationalize in decision making (e.g., include in accounting), among others.

6.2.4.2 Rights-based approaches

Rights-based approaches, at the substantive and procedural level, are multifaceted, and crucial to various aspects of governance including inclusive (e.g., participation rights) and informed (e.g., information rights) governance. In order to promote GQL, national laws and policies integrate the substantive right to a healthy environment, life, water, food, standard of living, and health (Knox, 2013, 2017; Draft Framework Principles on Human Rights and the Environment, 2018). Regional and national laws and policies also integrate procedural rights to information and participation in decision-making (Aarhus Convention, 1998; *Escazú Agreement, 2018;* Knox, 2013, 2017).

In addition, strong *land and sea rights*, including ownership and use rights, can promote local empowerment, reduce tensions between the authorities and resource users, and can be successfully integrated in community management of forests, use of non-timber forest products, communal grazing lands and subsistence fisheries (Oxfam *et al.,* 2016; FAO, 2012; Ring *et al.,* 2018; Acosta *et al.,* 2018; Stringer *et al.,* 2018). Granting land and sea rights to IPLCs is also a critical means for connecting IPLCs with environmental protection policies, including economic instruments such as carbon offsets, REDD+, PES and micro-credits (Gray *et al.,* 2008; de Koning *et al.,* 2011; van Dam, 2011; McElwee, 2012; Larson *et al.,* 2013; Duchelle *et al.,* 2014; Sunderlin *et al.,* 2014). As for *customary rights*, examples confirm that if competing interests between state and customary systems are adequately balanced, policy measures incorporating customary rights are likely to protect traditional values and ILK, respect local power structures and institutions of IPLCs, and contribute to biodiversity conservation (Acosta *et al.,* 2018; Willemen *et al.,* 2018). *Animal rights* are an example of non-anthropocentric development that recognizes intrinsic values of animals and the (ecological) interdependence of humans and animals (Birnie *et al.,* 2009; Kymlicka & Donaldson, 2011). *Rights of Nature* refers to the entitlement of nature with rights as a collective subject of interest, acknowledging its intrinsic values (Rühs & Jones, 2016; Gordon, 2017; Kotzé & Calzadilla, 2017; Rogers & Maloney, 2017). Policy options for the recognition of such rights often imply the articulation of a co-management regime (e.g., Whanganui River, New Zealand; Strack, 2017), and have been codified in national constitutions (e.g., Ecuador; Kauffman & Martin, 2017), national legislation (e.g., Bolivian Law of Mother Earth; Pacheco, 2014) and in local policies (e.g., United States; Sheehan, 2015). Also see Supplementary Materials section 6.1.2.

6.2.4.3 Gender

Gender literacy, women's empowerment, financial support, gender responsive approaches and integrating gender into nature conservation solutions are crucial to reinforce links between gender and biodiversity, achieve biodiversity objectives, and SDG 5 (gender equality) (CBD SBI/2/2 Add.3 (2018); IUCN, 2017). Lack of gender sensitive funding mechanisms and structural inequality hinder gender mainstreaming at the national and local level (Sweetman, 2015; UNEP, 2016). While *gender rights* acknowledge the interdependence between gender, biodiversity conservation

1. Motivational crowding means that the intended motivational impact of an incentive interacts and often changes the internal / intrinsic motivations of actors. Crowding-in means that an external incentive strenghtens intrinsic motivations, while crowding-out means that the incentive decreases intrinsic motivations to protect biodiversity (Rode *et al.,* 2015; Vatn *et al.*, 2014).

and sustainable use of resources (CBD Gender Plan of Action, 2008; Aichi Target 14, 17 and 20), poverty, religious and cultural practices (e.g., when gender disparities are entrenched in cultural and religious beliefs), and unequal social, economic and institutional structures are some of the key obstacles women encounter (CBD/IUCN, 2008; FAO, 2013; UNEP, 2016). The fundamental role women play in, among others, agriculture, forestry, fisheries, tourism, water management, wildlife management, and nature conservation and management underpin the need for effective participation in decision-making (Jenkins, 2017; Howard, 2015). To mainstream gender considerations, governments can take actions in policy (e.g., mainstream gender into NBSAPs), organizational (e.g., giving women collective and individual voice, gender equality training and awareness-raising among decision makers, and gender responsive budgets), delivery (e.g., participatory mechanisms, capacity development and empowerment to enable effective participation), and constituency (e.g., ensure consistency with relevant conventions) spheres (CBD Decision XII/7 (2014).

6.2.4.4 IPLCs and ILK

Inclusive governance requires robust participatory mechanisms supporting the inclusion of IPLCs in policies and planning decision affecting them and the environment at large (Bray *et al.,* 2008, 2012; Ojha *et al.,* 2009; Kerekes & Williamson, 2010; Kothari *et al.,* 2012, 2013; Mooney & Tan, 2012; Buntaine *et al.,* 2015). As discussed in chapter 2, IPLCs hold territorial rights and/or manage a substantial proportion of the world's conserved nature, freshwater systems, and coastal zones, providing contributions to society at large (Maffi, 2005; Gorenflo *et al.,* 2012; Renwick *et al.,* 2017; Garnett *et al.,* 2018). There is well-established evidence that IPLCs can develop complex, sophisticated, innovative and robust institutional arrangements and management systems for successfully governing the management of watersheds, coastal fisheries, forests and grasslands and a variety of biodiversity-rich landscapes around the world (Ostrom, 1990; Berkes, 1999; Agrawal, 2001; Colding & Folke, 2001; Lu, 2001; Toledo, 2001; Gadgil *et al.,* 2003; Bodin & Crona, 2008; Pacheco, 2008; Waylen *et al.,* 2010; Basurto *et al.,* 2013; Stevens *et al.,* 2014; Fernández-Llamazares *et al.,* 2016) to govern their land- and seascapes in ways that align with biodiversity conservation (ICC, 2008, 2010; Stevens *et al.,* 2014; Ens *et al.,* 2015, 2016; Trauernicht *et al.,* 2015; Blackman *et al.,* 2017; Schleicher *et al.,* 2017; Vierros, 2017).

The inclusion of IPLCs in governance can be enhanced through processes of knowledge coproduction at local, national and global scales (Brondizio & Le Tourneau, 2015; Sterling *et al.,* 2017; Wehi & Lord, 2017, Turnhout *et al.,* 2012; Tengö *et al.,* 2014, 2017; FPP & CBD, 2016; see also 6.2.2 and Chapter 1). Such enhanced participation has been shown to improve dialogue and advance the legitimacy of decisions and the recognition of the value and rights of IPLCs (Schroeder, 2010; Redpath *et al.,* 2013; Brugnach *et al.,* 2014; Wallbott, 2014, Brodt, 1999; Young & Lipton, 2006; Berkes, 2009; Davies *et al.,* 2013; Robinson *et al.,* 2014; Stevens *et al.,* 2014; Gavin *et al.,* 2015; Alexander *et al.,* 2016; Berdej & Armitage, 2016, Ostrom, 1990; Gibson *et al.,* 2005; Hayes, 2006, 2010; Chhatre & Agrawal, 2008, 2009; Waylen *et al.,* 2010; Porter-Bolland *et al.,* 2012; Reyes-García *et al.,* 2012; Gavin *et al.,* 2015; Martin *et al.,* 2016). However, long-term capacity development, empowerment and continued funding support are critical conditions to ensure IPLCs involvement in biodiversity conservation, including specifically women, youth and non-Indigenous communities (Brooks *et al.,* 2009; Ricketts *et al.,* 2010; Eallin, 2015; Escott *et al.,* 2015; Reid *et al.,* 2016; Reo *et al.,* 2017).

There are many tools available to set up such inclusive and participatory mechanisms (Green *et al.,* 2015; Pert *et al.,* 2015; Brondizio & Le Tourneau, 2016; Schreckenberg *et al.,* 2016; Fernández-Llamazares & Cabeza, 2017; Zafra-Calvo *et al.,* 2017), including IPLC-led codes of ethical conduct in conservation (e.g., Akwe: Kon Guidelines and The Tkarihwaié:ri Code of Ethical Conduct; CBD, 2004, 2011), the Free, Prior and Informed Consent principle (Cariño, 2005; Doyle, 2015; Herrmann & Martin, 2016; MacInnes *et al.,* 2017; UNDRIP, 2007), and tools for dialogue such as the Whakatane Mechanism (Freudenthal *et al.,* 2012; Sayer *et al.,* 2017), as well as legal approaches that draw inspiration from ILK and customary institutions (Archer, 2013; Hutchinson, 2014; Akchurin, 2015; Humphreys, 2015; Strack, 2017; also see rights-based approaches above). In this vein, the laws promoting the Rights of Nature (e.g., Bolivia, Ecuador, India, New Zealand) have been, in most cases, heavily influenced by IPLC philosophies placing nature at the center of all life (Akchurin, 2015; Díaz *et al.,* 2015; Borràs, 2016; Archer, 2013; Hutchinson, 2014; Strack, 2017; Kothari & Bajpai, 2017). Moreover, securing connection to place and granting land- and sea tenure rights to IPLCs are also a critical means to ensure IPLC participation in environmental governance and key enabling factors to IPLCs' well-being (Gray *et al.,* 2008; de Koning *et al.,* 2011; van Dam, 2011; McElwee, 2012; Larson *et al.,* 2013; Sunderlin *et al.,* 2014; Sterling *et al.,* 2017). Finally, global policy arenas such as IPBES and the CBD can facilitate knowledge co-production for enhanced environmental governance (Turnhout *et al.,* 2012; Tengö *et al.,* 2014, 2017; FPP & CBD, 2016). **Figure 6.1** outlines several public policies that can facilitate IPLC inclusion in transformative governance. Also see Supplementary Materials section 6.1.3 for background material on IPLCs and ILK, and **Box 6.3** for an example of inclusive governance.

Box 6 3 Example of Inclusive Governance – The Arctic Council.

The interconnected and complex challenges faced by the Arctic have been argued to be better addressed through transformative governance, including stronger transboundary cooperation and globally-coordinated policy responses (Aksenov *et al.,* 2014; Chapin *et al.,* 2015; Sommerkorn & Nilsson, 2015; Nilsson & Koivurova, 2016; Armitage *et al.,* 2017; Edwards & Evans, 2017; van Pelt *et al.,* 2017; Burgass *et al.,* 2018). As one of the fastest changing regions on Earth (ACIA, 2004; Wassmann *et al.,* 2011; Cowtan & Way, 2014), the Arctic is facing vast social-ecological challenges that have required all levels of governance –particularly the Arctic Council– to constantly adjust their modes of operation, ensuring a governance system that is transformative, flexible across issues and sectors, and adaptable over time (Axworthy *et al.,* 2012; Young, 2012; Chapin *et al.,* 2015; Ford *et al.,* 2015). The Arctic Council (AC), established in 1996, is an intergovernmental forum promoting cooperation, coordination and interaction among the Arctic States, Arctic Indigenous communities and other Arctic inhabitants on common Arctic issues, with an overall focus on encouraging transformative change towards sustainability (Young, 2012; Bloom, 1999; Axworthy *et al.,* 2012; Nilsson & Meek, 2016). Inclusiveness is an important principle for the AC and is best reflected by the unique formal status accorded to Arctic Indigenous Peoples as Permanent Participants, sitting at the table alongside State representatives (Bloom, 1999; Young, 2005). The AC has advanced the inclusion of Indigenous knowledge and expertise in AC assessment reports by placing Indigenous representatives in the steering committees of the different constituencies, task forces and working groups of AC (Kankaanpää & Young,2012) and has catalyzed Indigenous Peoples' participation in international policymaking more generally (Koivurova & Heinamäki, 2006). The AC has however also been criticized for continuing to rely on fixed governance fundaments (e.g., soft law nature, ad-hoc funding; Koivurova, 2009) and for failing to offer the kinds of firm institutional, financial and regulatory frameworks that are considered necessary (Berkman & Young, 2006; Greenpeace, 2014; Hussey *et al.,* 2016; Edwards & Evans, 2017; Harris *et al.,* 2018). (See for more details Supplementary Materials section 6.1.4).

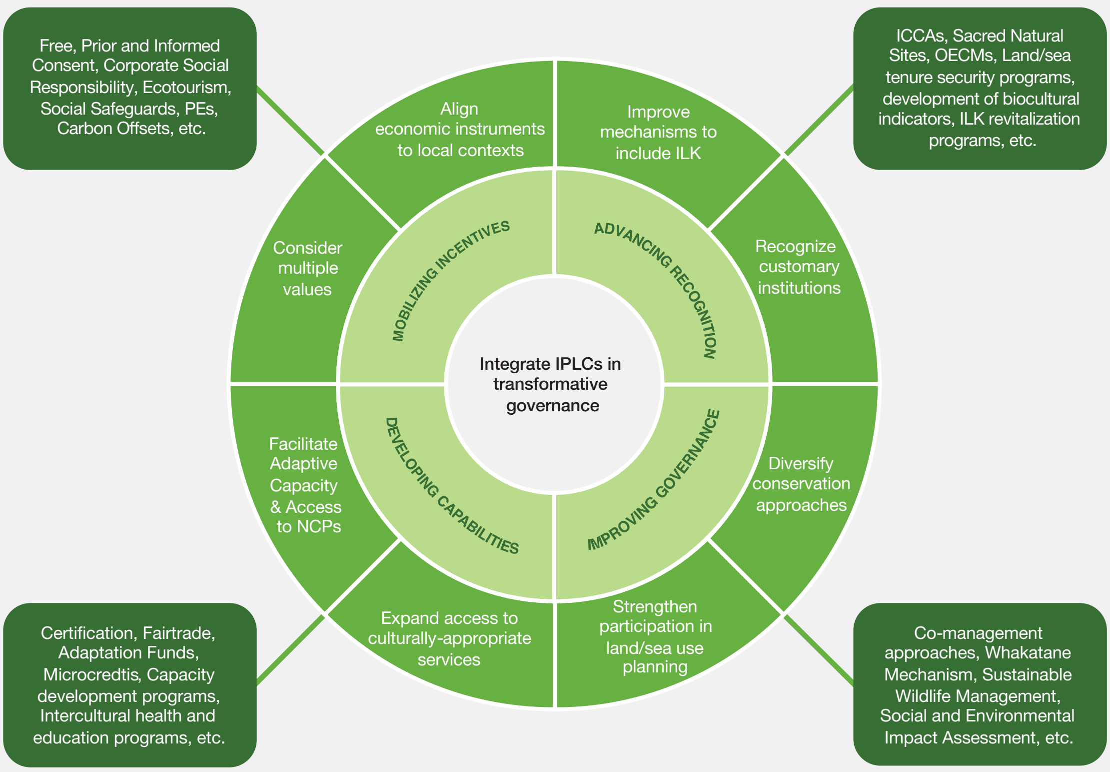

Figure 6 1 **Suite of policy opportunities and actions to better integrate Indigenous Peoples and Local Communities in transformative governance for sustainability.**

Design adapted from Strassburg *et al.* (2017).

6.3 TRANSFORMATIVE CHANGE IN AND ACROSS ISSUES, GOALS AND SECTORS

6.3.1 Introduction

As discussed in the above, the SDG are integrated and indivisible. Therefore, action on one SDG may (positively or negatively) affect progress on other SDG, and the implementation of different targets under an SDG are mutually dependent. Moreover, biodiversity is at the core of many of these complex interdependencies. To the global North and South, the comprehensive implementation of the goals offers major and different challenges to achieve sustainability in the environmental, social, and economic spheres.

Furthermore, as previous chapters have discussed, climate change is exacerbating and reinforcing other drivers of biodiversity loss and environmental degradation, such as habitat loss and degradation, agricultural expansion, unsustainable utilization, invasive alien species and pollution (particularly in marine and freshwater ecosystems; see Chapter 2.1). Various manifestations of climate change such as drought, extreme weather fluctuations, flooding, extreme heat and cold, storms, conditions for accidental fire, ocean water warming and acidification, and rising sea levels, are hindering our ability to meet the Aichi Biodiversity Targets and the SDG.

In this context, the aim of this section is to review both short-term (today-2030) and long-term (today-2050) options available to different decision makers **(Table 6.2)** to achieve the SDG on major biodiversity-related issues and policy domains, including terrestrial landscapes (6.3.2); marine, coastal and fisheries (6.3.3); freshwater (6.3.4); cities (6.3.5); and energy, mining and infrastructure (6.3.6). The overview table in each section summarizes the options that policy makers can include in policy mixes to together address the indirect drivers. The tables include the short- and long-term options, the main problems expected in their implementation, the main decision maker(s) involved, the main levels of governance involved (from the global to the local), and the main targeted indirect driver(s). Some of the common threads emerging from the synthesis below are the following:

First, integrated approaches within an SDG (various targets within one SDG) or among SDG (e.g., the water-food-energy-infrastructure nexus) offer opportunities to foster policy coherence, minimize unforeseen externalities and reduce potential conflict or tensions between different objectives or policies. Promising interventions include practicing integrated water resource management and landscape planning across scales, integrated coastal management, and bioregional scales for energy etc. In addition, policy mixes play a crucial role to address externalities and incorporate diverse values.

Second, data gathering, monitoring and reporting enable decision makers to understand the function and inter-related dynamics of nature, its contributions, and quality of life. Different types of assessment and analytical tools (e.g., cost benefit analysis, life cycle analysis, environmental impact assessment, strategic impact assessment, and participatory assessment) synthesize different types of knowledge, including indigenous and local knowledge. In addition, telecoupled information flows have the potential to contribute to monitoring, surveillance and control. Examples of these options are zero-deforestation pledges, certification schemes for key commodities or biofuel, and the use of satellite surveillance of at-sea fishing operations.

Third, collaborative efforts such as partnerships and other multi-stakeholder approaches among state, market and civil society actors can contribute towards achieving sustainability on all major issues discussed here. In addition, the development of robust, evidence-based, participatory and inclusive decision-making processes optimizes the participation of IPLCs and marginalized social groups (e.g., urban slum dwellers) in environmental governance. Enhanced participation and leadership of IPLCs in environmental processes can advance the recognition of the social, spiritual and customary values of IPLCs in environmental management decisions and influence the outcome, thereby enhancing their legitimacy.

Fourth, it is acknowledged that the effectiveness of policy instruments is context specific, and the implementation of different policy options needs to be adaptive. Moreover, the effectiveness of various policy instruments is not yet well understood and further research on the effectiveness of different policy options, separately and in combination, is necessary to achieve transformative change.

6.3.2 Integrated Approaches for Sustainable Landscapes

Landscapes are the geographical space where socio-ecological systems are shaped and develop. They are the most important source of food, water, materials and bio-energy, and provide space and quality for human habitation. Hence, landscapes are also the space where multiple land uses and values converge. Historically, landscapes have been governed by policies and decisions from different sectors and governance levels, i.e. agriculture, rural development, water, forestry, infrastructure, energy and urban planning, acting often independently without taking due consideration of the interdependencies and trade-offs among different societal objectives that often arise in landscapes.

The lack of articulation of these multiple objectives has been the cause of the large environmental, health and biodiversity loss challenges today, including the conversion and fragmentation of species habitats, one of, and in some regions the main driver of global biodiversity loss (Barnosky *et al.,* 2011; Ceballos *et al.,* 2015; Pimm *et al.,* 2014, Chapter 3 section 3.2.1), the levels of mechanization and resource inputs leading to landscape and biological homogenization (Newbold *et al.,* 2015; Pepper *et al.,* 2017), the lack of adequate attention for the protection of genetic resources of crops, trees, their wild relatives, and livestock (Collette *et al.,* 2015), the skewed representation of biodiversity in protected areas (Butchard *et al.,* 2012, 2015), and the loss of the capacity of soils, cropland and forested areas to maintain ecosystem services (Vitousek *et al.,* 1997; Schiefer *et al.,* 2016, Fornara *et al.,* 2008), including natural pest control and pollination. These challenges are associated with depletion, eutrophication and pollution of water, health problems related to undernourishment and simplified diets (United Nations, 2015), increased costs and risks in food and forestry production due to the introduction of invasive alien species (IAS), and the contribution of landscapes to greenhouse gas (GHG) emissions (FAO & ITPS, 2015, Supplementary Materials 6.2.1).

One unresolved question is how to shape landscapes that fulfil current and future needs of food and materials production, without the negative impacts on nature and society listed above. “Land-sparing” and “land-sharing” represent two extreme models about how landscapes can be shaped and refer to the degree of compatibility between different land use intensities, the conservation of biodiversity and generation of ecosystem services within a landscape (Balmford *et al.,* 2005; Fischer *et al.,* 2008; Phalan *et al.,* 2011, 2016, see also Supplementary Materials 6.2.1). This simplified dichotomy (“land sparing” vs. “land sharing”) limits future possibilities (Chapter 5 section 5.3.2.1). There is increasing consensus in that visions of sustainable land-use systems will lie in between these contrasting models, by considering the specific social, economic, ecological and technological context (Fischer *et al.,* 2008; Tscharntke *et al.,* 2012; Chapter 5 section 5.3.2.1). A landscape-focused participatory approach to policy design and implementation is an option to better address dilemmas about land use allocation and intensity of use.

This section analyses the evidence on the effectiveness of policy options that could be used by different decision makers to promote the transition to sustainable landscapes. To contribute to transformative change, options for sustainable agriculture and forest management and conservation would need to be approached with policy mixes (as discussed in 6.2.1 above on integrative governance): “…a combination of policy instruments that (evolves to) influence the quantity and quality of biodiversity conservation and ecosystem service provision in public and private sectors” (Ring & Schröter-Schlaack, 2011). These mixes can include policy instruments beyond the landscape, for instance to regulate the distance drivers of change (i.e., telecouplings) (see section *Regulating commodity chains,* below*)*, including the effect of distant consumption patterns (see section on *Encouraging dietary transitions and alternate consumption,* below).

A policy mix approach is motivated because even in simple settings, no single policy instrument is superior across all evaluation criteria (including effectiveness, cost-minimization, equity) (Vatn, 2010), and cannot possibly address all policy goals and targets. In contrast, well-integrated and implemented policy mixes can help counteract these and other deficiencies, such as economic externalities occurring with market power, unobservable behaviour and imperfect information; and address multiple jurisdictions and policy linkages across jurisdictions (Barton *et al.,* 2013). Successful policy mixes acknowledge the socio-ecological context (Andersson *et al.,* 2015), address conservation and sustainable use challenges, and recognize their cross-sectoral and multi-scale nature (Verburg *et al.,* 2013). If well planned, policy mixes can also address different objectives across the landscape, such as through a ‘policy scape’ perspective. A ‘policy scape’, understood as the spatial configuration of a policy mix (Barton *et al.,* 2013; Ezzine-de Blas *et al.,* 2016), recognizes the spatial variation of ecological and biodiversity features, suitability for sustainable food and materials production, and trade-offs between sustainable production and conservation (Schröder *et al.,* 2014; 2017).

Transformative landscape governance networks can further develop policy mixes that integrate across sectors, land uses, actors and levels of governance (Carrasco *et al.,* 2014), addressing important trade-offs among NCP in a transparent and equitable way. Options in the short and longer-term incorporate decision makers and stakeholders from within and outside the landscape while addressing power dynamics (Ishihara *et al.,* 2017; Berbés-Blázquez *et al.,* 2016). These networks are thus multi-actor (including different types of actors), multi-level (including multiple levels of governance, from the global to the local) (Verburg *et al.,* 2013), and multi-sector (including representatives from different sectors, including the entire value chain, from producer to end user) (Lim *et al.,* 2017). Decision makers and stakeholders in these networks need to recognize different values and be cognizant of power dynamics in the networks in order to enable transformative change. Any type of decision maker could initiate such networks.

The options discussed in the remainder of this section, and summarized in **Table 6.3**, can be potential elements of these policy mixes for integrated landscape approaches. They mainly include existing instruments aimed to support sustainable agriculture, sustainable forest management and biodiversity conservation, and thus represent options that can be implemented in the short term. Water governance, although an integral part of landscapes, is discussed in section 6.3.4. However, it is only when these options are strategically combined in integrated landscape approaches that transformative change towards sustainability can take place. Such approaches can be started in the short term but need to be continuously enhanced through transformative governance in the longer term.

Table 6 3 **Options for integrated approaches for sustainable landscapes.**

Short-term options (incremental and transformative)	**Long-term options (in the context of transformative change)**	**Key obstacles, risks, spill-over, unintended consequences, trade-offs**	**Major decision maker(s)** (see Table 6.2)	**Main level(s) of governance**	**Main targeted indirect driver(s)**
Sustainable landscapes					
Harmonized, synergetic, cross-sectoral, multi-level and spatially targeted policy mixes, developed through transformative landscape governance networks		Sectoral policy formulation; limited resources and technical capacity; limited resolution of trade-offs; lack of policies inclusive of the entire market that address leakage and telecoupling	Governments; Science and educational organizations; private sector; civil society, IPLCs	All	Economic; institution; governance
Feeding the world without consuming the planet					
Expanding and enhancing sustainable intensification in agriculture (including crops and livestock)		Limited public investment in innovation and outreach activities; limited research and innovation in production embracing sustainability principles; economic and social inequalities	FAO, OIE, governments; science and educational organizations; civil society; donors	National and sub-national	Technological; economic
Encouraging ecological intensification and sustainable use of multi-functional landscapes		Lack of cross-sectoral policy integration; potential high risk of conflict with conservation; limited spatial/territorial planning; limited capacity to resolve trade-offs; lack of understanding about production benefits from improved biodiverse/multiple-value use of land; limited landholder buy-in; pressure to further intensify ('productivist' agricultural paradigm)	Governments; science and educational organizations; private sector; civil society; donors	National; sub-national and local	Institutions; governance; economic
Improving certification schemes and organic agriculture		Limited demand for certified products; lack of landscape level coverage; risk for leakage; voluntary; tends to prioritize brokers and industries; less participation of poor farmers; requires market integration; standards unclear for consumers	Civil society; private sector; governments	Global; regional; national	Cultural; institutions; economic; governance; technological
Regulating commodity chains		Small-farmer exclusion due to high transaction costs of certification and lack of domestic markets; limited expansion of certified area; risk of limited acknowledgement of local customary rights; lack of effective external control; promotion of segregated landscapes; overlooks root causes of land-use expansion; voluntary standards	Civil society; private sector	Global; regional; national	Institutions; governance; cultural; economic
Conserving genetic resources for agriculture		Lack of integration of local genetic resources networks and global processes; lack of integration of genetic resources in biodiversity conservation; risk of increasing social and economic inequalities; lack of recognition of IPLCs and intellectual property rights; limited trait control and seed quality standards	Global and regional (inter-) governmental organizations; private sector; IPLCs; science and educational organizations	All	Institutions; governance; technological

Short-term options (incremental and transformative)	Long-term options (in the context of transformative change)	Key obstacles, risks, spill-over, unintended consequences, trade-offs	Major decision maker(s) (see Table 6.2)	Main level(s) of governance	Main targeted indirect driver(s)
Managing Large-Scale Land Acquisitions (LSLA)		Risk of leakage effects; social and economic marginalization of local farmers; increased tenure insecurity in surrounding lands	Intergovernmental organizations, private sector; farmers	All	Economic; institutions, governance
Encouraging dietary transitions		Lack of consumer awareness of environmental, health and animal welfare implications of food types; lack of effectiveness of information campaigns; voluntary labeling of products; limited market shares of certified products, labeling often emphasizing documentation not performance; low price of unsustainable food	National, subnational and local governments; private sector; citizens; NGOs, science and education organizations	All	Economic; cultural
Reducing food waste	Transformations in food storage and delivery	Failures in food distribution and storage systems; limited consumer education; wasteful marketing practices; limited recycling of food waste; wasteful supply chains and business models	Private sector; citizens (consumers); national and subnational governments; donors; science and education organizations	National; subnational; local	Institutions; governance; cultural
Improving food distribution and localizing food systems		Disconnect between production, consumption and waste management; poor integration in urban planning; limited connection between producers and consumers	National and subnational governments; private sector; citizens (consumers)	National and subnational	Economic; institutions; governance; technological
Expanding food market transparency and price stability		Opposition to government role in stabilizing food prices and food security; limited social targeting to support poor populations	Intergovernmental organizations; National governments; private sector	National	Governance; economic; institutions
Sustainably managing multi-functional forests					
Expanding and improving community-based forest management and co-management		Bureaucratic (and political) apathy; institutional resistance from forest bureaucracies	Governments; civil society; IPLCs	National; sub-national and local	Institutions; governance; demographic
Improving policies relating to PES and REDD+		Informational and other asymmetries among stakeholders; complexities in benefit sharing; unclear or contested tenure; unfavorable institutional and policy settings; over-prioritization of market incentives; limited range of ecosystem services compensated for; international disagreement; trade-offs and conflicts between carbon and other benefits (including biodiversity conservation); stakeholders not always involved in policy design	Global institutions (UN, MEAs); governments; donor agencies; civil society	All	Governance; institutions; economic; technological
Supporting Reduced Impact Logging (RIL)		Insufficient technical and financial capacity, especially in forest-rich tropical countries	Governments; science & educational organizations, private sector	National; sub-national and local	Technological; economic
Promoting and improving forest certification		Limited technical and financial capacity for forest management; low demand for certified products; lack of information among consumers	Governments; science & educational organizations; private sector; NGOs; donors	All	Economic; institutions; governance; cultural; technological
Controlling illegal logging		Weak local governance, poor level of compliance; difficulties with monitoring and traceability; insufficient reward for legal forest harvests in global timber market; difficulties with monitoring and traceability	Intergovernmental organizations; governments; private sector, donors; civil society	All	Governance; institutions; economic

Short-term options (incremental and transformative)	Long-term options (in the context of transformative change)	Key obstacles, risks, spill-over, unintended consequences, trade-offs	Major decision maker(s) (see Table 6.2)	Main level(s) of governance	Main targeted indirect driver(s)
Monitoring and regulating forest use		Insufficient technical and financial capacities; poor understanding of the needs and benefits; weak local governance; poor level of compliance; difficulties with monitoring and traceability systems	International organizations (e.g. FAO); governments; educational organizations; IPLCs	All	Governance; economic, technological
Protecting nature					
Improving management of protected areas (PAs)		Inadequate resources and weak governance; increased human pressures; climate change; limited enforcement, limited monitoring; lack of robust ecological data to assess effectiveness across spatial & temporal scales	International organizations (e.g. IUCN); governments; NGOs; donors	All	Governance; institutions; technological
	Improving spatial and functional connectivity of PAs	Isolation of PAs; geographical and ecological biases; limited spatial planning; trade-offs among societal objectives	Global organizations; governments; NGOs; donors	All	Governance; institutions; technological
	Improving transboundary PA and landscape governance	PA planning usually depends on individual governments	Global organizations; national governments; NGOs; donors	All	Governance; institutions
Recognizing management by IPLCs and OECMs		History of conflicts between IPLCs and legal PA management; potential displacement, exclusion, distress of IPLCs due to strict PA governance; unequal sharing of costs and benefits between different actors; erosion of ILK	Governments; NGOs; private sector; IPLCs; donors	All	Cultural; governance; institutions; regional conflicts
Addressing the illegal wildlife trade		Poor law enforcement; limited capacity for detection; limited surveillance; corruption; limited capacity of crime investigation	Global institutions (CITES); national governments; citizens; IPLCs; NGOs	All	Governance; cultural; economic
Improving Sustainable Wildlife Management		Lack of recognition of IPLC rights; unequal distribution of benefits; elite capture; leakage effects; lack of enforcement of law and international agreements; corruption	Governments; IPLCs; private sector; NGOs	All	Governance; institutions; economic
Manage IAS through multiple policy instruments		Legal and institutional barriers to effective management; information management challenges; lack of resources; limited perception of risks; jurisdictional issues; lack of coherent systemic and community-partnered approach to IAS management; lack of economic incentives to engage private landowners; limited engagement of IPLCs	Global organizations; governments	All	Governance; institutions; cultural; technology; economic
Expanding ecosystem restoration projects and policies					
Expanding ecosystem restoration projects and policies and link to revitalization of ILK		Uncertainty about effectiveness; limited formal and empirical evaluation of projects; risk for limited acceptance of project (neglect of community culture and values); rapid cultural change	Governments; science and education organizations; private sector; IPLCs	National and local	Technology; economic; cultural
Improving financing for conservation and sustainable development					
Improving financing for conservation and sustainable development		Lack of understanding of what financing mechanisms are most effective; priorities for financing in other sectors above biodiversity; lack of consistent monitoring of ODA for biodiversity	Global organizations; national governments; donors	Global; regional; National	Economic; governance; institutions

6.3.2.1 Feeding the world without consuming the planet

Expanding and enhancing sustainable intensification in agriculture

To address land degradation (IPBES, 2018b) and other environmental impacts of agriculture, two forms of ecological modernization are currently considered: (i) sustainable intensification (Sustainable intensification or efficiency-substitution agriculture (Duru *et al.,* 2015, Schiefer *et al.,* 2016), which aims to improve input use efficiency and minimize environmental impacts. This is currently the dominant modernization alternative (see Supplementary Materials 6.2.2; Chapter 2.3 about trends in production for marketed commodities). (ii) *biodiversity-based agriculture* aims to develop agriculture enhancing ecosystem services generated by agro-diversity (Duru *et al.,* 2015) (see section on "Encouraging sustainable use of multifunctional landscapes", below).

Efficiency-based agriculture consists of adjusting practices in specialized systems to comply with environmental regulations and follows the logic of economy of scale and expression of comparative advantages (e.g., for soil fertility, climate, knowledge, labour costs, infrastructure, and regulations) (Duru *et al.,* 2015), aiming at closing yield gaps (Mueller *et al.,* 2012, Chapter 5 section 5.3.2.1). Implementation is based on good agricultural practices (e.g. FAO), and international voluntary standards, including those on animal health and welfare of the World Organization for Animal Health (OIE), and uses also new technologies such as precision agriculture (Supplementary Materials 6.2.2).

The adoption of these practices can be supported by investment in technological development and outreach, regulations, and public and private quality standards such as voluntary certification schemes and roundtables (see sections on *Improving certification schemes* and *Regulating commodity chains*, below). One recent example of the mixes of measures that can promote this kind of agricultural modernization is the program to encourage the sustainable increase of crop yields in smallholder farms in China. In 2003–11, the country increased its cereal production by about 32% (more than double the world average), largely by improving the performance of the least-efficient farms, through a comprehensive package of measures that included public investment, development and testing of technologies adapted to specific agro-ecological zones that improved yields, conserved soils and reduced fertilizer application, and outreach and farmer engagement (Zhang *et al.,* 2013). Development of new crop varieties remains one of several areas of fundamental research that feed into this approach to increase yields and reduce the use of insecticides (Zhang *et al.,* 2013).

Efficiency agriculture is applied to both crops and livestock production. Industrial production systems produce over two-thirds of global production of poultry meat, almost two-thirds of egg production and more than half of world output of pork, with beef and milk production remaining less intensified (FAO, 2009). The environmental impacts, including water, soil and air pollution, of intensive livestock production are significant, and these systems often harbor poor animal welfare conditions (HLPE, 2016). Challenges of efficiency agriculture, including the industrial production of livestock, generally rely on high levels of anthropogenic inputs and include the extensive use of non-renewable resources such as mineral fertilizers and energy, the risk of pest resistance to agro-chemicals (Duru & Therond, 2014), human health problems associated with the use of pesticides and veterinary drugs, the homogenization of crops, and the biological deterioration of the land. This kind of intensification may trigger land conversion as has been the case of soybean expansion in South America (Fearnside, 2001; Pacheco, 2012). Shortcomings can also involve leakage effects and failure to address the conservation of semi-natural and open habitats (Supplementary Materials 6.2.2), issues due to the shift of agricultural production from small and medium household farms to international agroindustry pools (Strada and Vila 2015), and exposure to market volatility.

Encouraging ecological intensification and sustainable use of multi-functional landscapes

Land-use systems consisting of mosaics of cropland, grasslands and pastures, and forests, are widely spread globally and are critical for food security and sovereignty (Supplementary Materials 6.2.2). Encouraging use of multi-functional landscapes can be the basis for a shift towards *ecological intensification or biodiversity-based agriculture* including diversification of food sources, ecological rotation and agroforestry, promotion of agroecology with a view to promoting sustainable production and improving nutrition (McConnell, 2003). At the same time, these landscapes are the space where the largest conflicts with nature conservation can take place (Ravenelle & Nyhus, 2017), especially in the case of wildlife – human interactions.

Multi-functional landscapes also support NCP critical to IPLC diets and food systems. These are also gaining attention in the context of global discourses around food sovereignty (Patel, 2009) and cultural identity (Charlton, 2016; Coté, 2016; Kuhnlein *et al.,* 2009; Nolan & Pieroni, 2014). Many IPLCs and a wide range of rural and peri-urban populations, remain highly dependent on hunting, fishing and gathering for their diets, which play a critical role in supporting IPLC health and well-being (Kuhnlein, 2014; Kuhnlein & Receveur, 2007; ICC, 2015; Nesbitt & Moore, 2016). As such, drivers of landscape homogenization and biodiversity loss have been largely associated with rapid nutritional shifts among IPLCs, through the reduction in consumption of locally-sourced foods as well as the incorporation of industrially processed products, often leading to increasing rates of overweight, obesity and chronic disease (Popkin, 2004; ICC, 2015; Galvin *et al.,* 2015; Iannotti and Lesorogol, 2014; Reyes-García *et al.,* 2018). Measures to promote multi-functional landscapes are easier to govern when they are broadly defined and linked to values or objectives in the sector or local practices (Runhaar *et al.,* 2017). Community-driven and culturally-appropriate responses to address these changes posit a reconnection of land-based food systems and have recurrently called for supporting the recognition of IPLC food sovereignty (Wittman *et al.,* 2010; Morrison, 2011; Rudolph & McLachlan, 2013; Martens *et al.,* 2016). Also, targeting specific measures by identifying agro-ecological constraints and characteristics of farming systems such as population pressure, urbanization, governance, income and undernourishment, can further help select suitable measures to promote ecological intensification in agriculture (Sietz *et al.,* 2017) and the management of NCP based on biodiversity.

Policy options that have been implemented to promote ecological intensification of farming systems include, although not exclusively, direct payments such as agri-environmental schemes (AES) to conserve and better provision ecosystem services (Supplementary Materials 6.2.2) and to maintain and restore habitats (Montagnini *et al.,* 2004), payments for ecosystem services (PES) to protect water sources (Frickmann Young *et al.,* 2014), with biodiversity conservation as a co-benefit (see section on *Improving REDD+ and PES),* below), and standards and certification schemes (see section on *Improving Certification Schemes and Organic Agriculture*, below). A form of biodiversity-based agriculture is permanent (agri)culture, based on broad principles defined as mimicking ecological patterns, locally designed and recuperation of traditional ecological practices (Roux-Rosier *et al.,* 2018).

Technical assistance and investment (including micro-credits) have been used to promote land uses such as agro-forestry systems that enhance on-farm provisioning (e.g. timber and non-timber products in addition to crops and pastures (Montagnini, 2017, Part III) and regulating services such as carbon sequestration. Direct payments (e.g., PES) can be combined with technical assistance since they are effective in overcoming initial economic and technical obstacles to the adoption of agro-forestry practices (Cole, 2010), but the practices need short to medium-term technical support to ensure their long-term retention. These measures have been combined with REDD+ (see section on REDD+, below) to promote carbon sequestration and halt forest clearing.

Participatory approaches and compensation schemes have helped resolve conflicts between food and material production and nature conservation, including wildlife conservation in these mixed-use systems (see section on *Improving Sustainable Wildlife Management*, below) where multiple objectives converge. Finally, the farmers' level of adoption of practices in voluntary schemes (AES, PES, REDD+, technology adoption and certification schemes) is, in many instances, low and largely determines the effectiveness of the measures (Giomi *et al.,* 2018; Runhaar *et al.,* 2017). Two obstacles related to direct payments, a widely used policy instrument, include its voluntary character and that subsidies often do not cover all costs (Runhaar *et al.,* 2017). Farmers who do not voluntarily engage in nature conservation could be incentivized by showcasing farmers who have made advances, critical consumers, and stricter rules in direct payment schemes or in generic agri-environmental legislation (Giomi *et al.,* 2018). Farmers need to be motivated, able, or enabled (e.g. through investment in technological development and outreach), demanded (through regulations and quality standards as the IFOAM-Organic standard and roundtables (see *Improving Certification Schemes and Organic Agriculture*, below), and legitimized to participate and act (Runhaar *et al.,* 2017). There are also other private forms of governance including the cooperation of farmers with conservation NGOs, or compliance to conservation standards requested by companies in agricultural supply chains as part of their Corporate Social Responsibility programmes (Runhaar *et al.,* 2017).

Improving certification schemes and organic agriculture

Over the last decades, voluntary sustainability standards (VSS) and certification schemes (VCS) have become a key governance mechanism affecting land-use decisions and land-use shifts (Sikor *et al.,* 2013) aiming to mitigate the negative impacts of agricultural expansion and intensification, including deforestation (Milder *et al.,* 2014; Tscharntke *et al.,* 2015), by promoting environmental and biodiversity-friendly practices at the farm level. Studies reveal increases in the abundance or species richness of a wide range of taxa, including birds and mammals, invertebrates and arable-land flora in certified farms (Hole *et al.,* 2005; Bengtsson *et al.,* 2005; Tuomisto *et al.,* 2012; Tayleur *et al.,* 2018), and ecosystem services (Supplementary Materials 6.2.2, Kremen *et al.,* 2002; Bengtsson *et al.,* 2005; Hutton & Giller, 2003), mainly due to lower agrochemical inputs (Aude *et al.,* 2003; Hutton & Giller, 2003; Pimentel *et al.,* 2005; Birkhofer *et al.,* 2008)

However, most certification schemes are too recent to evaluate detectable impacts (Tayleur *et al.,* 2018) and results on environmental and biodiversity performance are in many cases limited (Gulbrandsen, 2010; Gulbrandsen, 2009) or variable (Bengtsson *et al.,* 2005). In some cases, certification schemes have spurred more intensive and degrading land-use practice (Guthman, 2004; Klooster,

2010) and caused higher deforestation in neighbouring old-growth forest areas (Tayleur *et al.,* 2016).

A few studies have also documented positive livelihood outcomes from certification (Bacon, 2005; Bolwig *et al.,* 2009; Gulbrandsen, 2005; Ruben and Fort, 2012) and improved management institutions, but impacts on poverty alleviation are mixed (Yu Ting *et al.,* 2016). Many schemes have exacerbated problematic political and economic inequalities (Gómez Tovar *et al.,* 2005; Ponte, 2008) or failed to enhance market access or benefits (Font *et al.,* 2007), especially for smallholder farmers (DeFries *et al.,* 2017; Tayleur *et al.,* 2018). There are also issues of high transaction costs, transparency, legitimacy and equity in certification schemes (Supplementary Materials 6.2.2; Eden, 2009; Klooster, 2010; Havice & Iles, 2015; Hatanaka *et al.,* 2005).

Certification of tropical agricultural commodities shows clear aggregations in Central America, Brazil, West Africa and parts of East Africa and Southeast Asia and has poor representation in the world's 31 poorest countries (Tayleur *et al.,* 2018), and schemes remain limited in geographic scope (Ebeling & Yasué, 2009; Rametsteiner & Simula, 2003, Tayleur *et al.,* 2016).

Certification could better contribute to sustainability goals if targeted where benefits can be optimized (Tayleur *et al.,* 2016), i.e. areas of high nature conservation value (including landscape level quality) (Hole *et al.,* 2005), in areas of social and economic development priority, and where enabling conditions exist (e.g. governmental complementary policies) (Tayleur *et al.,* 2016). Governments can facilitate the impact of certification schemes by promoting certification uptake and supporting strategic targeting. Governments involved in international aid could engage in coordinating efforts to finance certification in identified priority areas for social and economic development (Tayleur *et al.,* 2016).

Public campaigns on the environmental, health, conservation, and social benefits of certified products are likely to increase consumer demand for these products, and measures aiming to enhance social responsibility in multi-national corporations can be effective (Tayleur *et al.,* 2018). Engaging in more equitable food value chains (see sections on *Improving food distribution and localizing food systems*, *Expanding food market transparency and price stability* and *Regulating commodity chains*) have the potential to expand the geographical range and enhance social outcomes. Critical to promoting VCS that balance conservation and economic demands is: 1) managing stakeholder expectations; 2) targeting priority habitats, species and social groups and 3) implementing adequate post-certification monitoring of impacts (Yu Ting *et al.,* 2016; Tayleur *et al.,* 2018). New technology (e.g., environmental data management and sharing infrastructure, modelling, web-based communication) and data availability could help improve monitoring and assessment of certification impacts, including bio-physical (e.g., nutrient leakage, water use efficiency, biodiversity), social and economic criteria.

Regulating commodity chains

Two major efforts to regulate commodity chains, particularly for tropical agricultural products, and to deal with telecoupling issues and the unsustainable expansion of these commodities include multistakeholder fora and commodity moratorium policies. Examples of multistakeholder fora are the Roundtable on Sustainable Palm Oil (RSPO), the Roundtable on Responsible Soy (RTRS) Better Sugar Cane Initiative, and the Roundtable on Sustainable Biomaterial, which aim to engage all private stakeholders of an agricultural supply chain, including growers; processors; consumer goods manufacturers; environmental NGOs; social NGOs; banks and investors; and retailers to establish a "sustainability" standard, and unlike labels that focus on a specific market, these standards envision to transform the entire sector towards sustainability. However, the RSPO standard overlooks the root causes of palm oil expansion in the tropics, such as land rights, commodity prices, agricultural systems and market access, resulting in a rather small and local level impact of certification on biodiversity conservation (Ruysschaert & Salles, 2014; Ruysschaert, 2016). At the global level, the RSPO is promoting a segregated landscape with large-scale plantations and conservation areas. This could make sense, as large oil palm plantations are very productive. However, this fails to recognize that the main environmental and social gains can be made by supporting smallholders, who currently produce half as much as the large-scale plantations (Ruysschaert, 2016; GRAIN, 2016).

Although the RSPO standards may be based on principles of inclusive participation from each member category; consensus building; and transparency in the negotiation process (RSPO, 2013, Schouten & Glasbergen, 2011), in practice, its implementation is more complex, with RSPO certification favouring three dominant groups of stakeholders: the downstream agro-business firms, international environmental NGOs, and the largest palm oil producers (Ruysschaert, 2016). For the downstream firms, RSPO certification fulfils their initial goal to secure their business in the long-term and protect their reputation (RSPO, 2002), but it often fails to cover costs of producers, particularly, the forgone economic opportunity to convert the areas identified as high conservation value (HCV) (Ruysschaert & Salles, 2014). RSPO has tended to favour large-scale producers seeking to get access to international markets; smaller firms and smallholders are largely excluded either because they sell to domestic markets where certification is not valued by consumers, or because they find certification too costly and its managerial requirements too demanding (Ruysschaert & Salles, 2014; Ruysschaert, 2016; and Supplementary Materials 6.2.2)

The case of moratoria such as the Brazilian Soy Moratorium (Supplementary Materials 6.2.2) appears to have been more successful in delivering biodiversity conservation outcomes (i.e. halting deforestation, Rudorff *et al.,* 2011; Gibbs *et al.,* 2015) and has set the stage for other initiatives to improve the sustainability of soy production and raise the awareness of the markets, like the RTRS and the Soja Plus Program. These initiatives are additional to zero-deforestation agreements and include other issues related to environmental compliance, social justice and economic viability at the farm and the supply chain level. Although there are leakage risks due to Moratorium restrictions (Arima *et al.,* 2011), recent analysis is showing no evidence for this (Le Polain de Waroux *et al.,* 2017). In contrast, there are opportunities for soy production in degraded pasture areas without increasing deforestation; combined with the identification of suitable areas, pasture intensification techniques and controlling new deforestation, the soy supply chain in the Amazon may become a good example of reconciliation of forest conservation and agricultural production. However, despite the good results, there are still threats to the Moratorium. Policy mixes supporting this package of measures can be enhanced if they address failures related to market shares, like the lack of engagement of traders and importers and the competition with farmers not covered by the Moratorium, which may further demise the motivation of the private sector in keeping the agreement.

Conserving genetic resources for agriculture

The diversity of cultivated plants, domestic animals and their wild relatives is fundamental for food security globally (Asia, Africa, Central and South America) (McConnell, 2003; Dawson *et al.,* 2013), and essential to the adaptation of agriculture to new and uncertain patterns of climate change. Most of the global genetic diversity in agriculture is kept in low-input farming systems (McConnell, 2003), and it is central to food sovereignty and to food as a non-material contribution to GQL (Chapter 1), also in IPLCs, where it can also involve cultural keystone species which support community identity and traditional roles (e.g. taro in the Pacific, corn in Central and South America, buffalo in North America). Globally, policy options to protect genetic resources for agriculture and forestry include support to on-farm conservation (*in situ*) (Enjalbert *et al.,* 2011; Thomas *et al.,* 2012, 2015) integrated with the conservation of germplasm in gene banks (*ex situ*). *In situ* conservation requires that the farmers, livestock keepers and foresters who conserve and manage these varieties, breeds and species benefit from maintaining this global common resource (CBD, 2014 Nagoya Protocol; Collette *et al.,* 2015). The genetic diversity in agriculture underlie current debates on food and seed sovereignty, and the implications of intellectual property rights to conservation of biodiversity and plant germplasm (Coomes *et al.,* 2015, see also Chapter 2.1 section 2.1.9.1.1). The debates have involved researchers, policy makers, seed producers for the market and IPLCs, bringing tension over seed legislation, regulation and commercialization (FAO, 2004; CBD The Nagoya Protocol, 2014; European Seed Association, 2014).

The case of social networks (e.g. farmer seed networks and community seed banks (Coomes *et al.,* 2015; Pautasso *et al.,* 2013; Lewis & Mulvany, 1997), illustrate the potential and challenges of the conservation and sustainable use of local genetic resources of global significance. Seed networks are cornerstones in maintaining the diversity of crops and their wild relatives (Tapia, 2000); they account for 80-90% of the global seed transfers and supply (Coomes *et al.,* 2015) and are important channels of innovation and diversity (Coomes *et al.,* 2015), and therefore show considerable potential for innovation and transformation of agricultural systems aligned with the SDG, especially if entry points for improvement are identified (Buddenhagen *et al.,* 2017). Seed networks are found in all regions of the world: Central and South America, Africa, Asia; in the Australia, Canada, the UK and the USA, and particular types of community seed banks have emerged (Vernooy *et al.,* 2015; Dawson *et al.,* 2011; Urzedo, 2016).

Options examined in the literature include aspects of seed quality and distribution, social and economic dimensions and global governance issues. Developing quality standards for traits, seeds and other material, and quality control schemes would considerably enhance the potential for integration into global processes of sharing and exchange of genetic resources (Coomes *et al.,* 2015; Jarvis *et al.,* 2011), but the mechanisms of seed sharing require attention, so that barriers that discriminate disfavored social groups can be addressed and eliminated (Tadesse *et al.,* 2016). Vernooy *et al.* (2017) summarize a series of measures to maintain *in situ* genetic diversity, which include support to local institutions, actively protect plants and livestock breeds that can survive extreme conditions, facilitate the restoration of varieties no longer used, develop platforms to facilitate access and availability of seeds at the community level, and help access novel diversity not conserved locally. Since in many cases, farmers have few market or non-market incentives, different public measures will be necessary to protect genetic resources (Jarvis *et al.,* 2011).

Given that these resources are of global importance (see also Chapter 2.2 section 2.2.3.4.3 on agro-biodiversity hotspots and Chapter 3 on Aichi Target 13) the national and global mechanisms need to be developed and harmonized. Global mechanisms are governed by three agreements originating from different sectors: The Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization under the CBD (CBD, 2014; Nagoya Protocol), the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (FAO, 2004), and the International Convention for the Protection of New Varieties of Plants (UPOV http://www.upov.int/portal/index.html.en). Despite efforts to harmonize implementation, there are considerable gaps in the coordination of the agreements.

Managing large-scale land acquisitions (LSLA)

Concerns about LSLA (also sometimes called "land grabbing") have increased considerably over the past decade (Borras *et al.,* 2011; Balehegn *et al.,* 2015) and include issues of food security, equity, leakage and environmental effects (Grant & Das, 2015; Coscieme *et al.,*, 2016; Borras *et al.,* 2011; Adnan, 2013). While some see land acquisitions as investments that can contribute to more efficient food production at larger scales (World Bank, 2010; Deininger & Byerlee, 2012), there are strong concerns that food security (especially at local levels) may be threatened by these large agribusiness deals (Daniel, 2011; Lavers, 2012; Golay & Biglino, 2013, Ehara *et al.,* 2018; and Supplementary Materials 6.2.2).

Displacement of smallholders from LSLA can potentially lead to impoverishment and increased (unsustainable) production elsewhere once they are removed from lands (Borras *et al.,* 2011; Adnan, 2013); these have happened with frequency in many countries in Africa, where communal land tenure authorities have allowed expropriation of locally used lands without other farmers' knowledge or compensation (Osinubi *et al.,* 2016). There is some evidence that LSLA have already led to the impoverishment of some communities and as many as 12 million people (Adnan, 2013; Davis *et al.,* 2014). In at least some cases, the causal process is that land grabs contribute to increased tenure insecurity in surrounding lands, leading farmers to shift to cultivating smaller farms with less investments, potentially leading to food shortages (Aha *et al.,* 2017). There is some evidence that land grabbing is also weakening local systems of common property management, which can make some communities less able to adapt to climate changes in the future (Gabay & Alam, 2017; Dell'Angelo *et al.,* 2017), including reducing the forest resources they may depend on as safety nets (Kenney-Lazar, 2012).

The primary policy mechanisms for combatting large scale land acquisitions have included restrictions on the size of land sales (Fairbairn, 2015); pressure on agribusiness companies to agree to voluntary guidelines and principles for responsible investment (Collins, 2014; Goetz, 2013); attempts to repeal biofuels standards (Palmer, 2014); and direct protests against the land acquisitions (Hall *et al.,* 2015; Fameree, 2016). REDD+ has the potential to provide a counterbalance with funding to combat land grabbing, but evidence is unclear if this is really happening yet or if REDD+ will mostly protect areas not under threat from large-scale investments (Ziegler *et al.,* 2012; Phelps *et al.,* 2013). Some have also accused REDD+ projects of being akin to land grabs in that they may displace smallholder agriculture without proper compensation (Lyons & Westoby, 2014; Corbera *et al.,* 2017). Future policies to regulate LSLA will need to rely on better monitoring data as a first step, as it is difficult to track the scale and impact of such LSLA.

Encouraging dietary transitions

The characteristics of today's global(ized) food system and the increasing industrialization of agricultural production, food consumption, and in particular animal protein consumption, are associated with a range of challenges, including food sovereignty, biodiversity loss, climate change, pollution, and animal health and welfare (HLPE, 2016; Steinfeld *et al.,* 2006; Garnett *et al.,* 2013; HLPE, 2016; Visseren-Hamakers, 2018; McMichael *et al.,* 2007; Jones & Kammen, 2011; Tilman & Clark, 2014). These problems are especially urgent given the fact that the global production of different animal products is expected to double by 2050 (Steinfeld *et al.,* 2006). The expansion of soybean in South America illustrates the challenges of current globalized industrial food production, with 45% of livestock feed in the EU based on soybean imported from Brazil and Argentina (EEA, 2017; Strada & Vila, 2015).

Current consumption of animal products is very unequally distributed, and animal protein can continue to play a role in ensuring food security in much of the developing world (Steinfeld & Gerber, 2010). However, substantially reducing the consumption of animal products in developed countries and emerging economies has the potential to greatly lower the negative impacts of farming while at the same time generating significant dividends in terms of people's health (Pelletier & Tyedmers, 2010; Smith *et al.,* 2013; Tilman & Clark, 2014; Bajzelj *et al.,* 2014; Ripple *et al.,* 2014; Springmann *et al.,* 2016, see also Chapter 2.3).

Different types of policy instruments aimed at lowering and changing consumption have been tried and studied (Story *et al.,* 2008; Vinnari & Tapio, 2012). Informational policy instruments aim to foster more sustainable food choices by offering information on production characteristics or health implications of food types or products. They range from certification schemes and (requiring) labels listing product ingredients or voluntary labels, signaling superior production methods (in terms of environmental, social or animal welfare aspects), to health campaigns (Reisch *et al.,* 2013), and would seem promising given a lack of consumer awareness of the implications of animal protein, an inaccuracy of messages on the health implications of (red) meat consumption, and the potential for altering relevant consumer attitudes and motivations identified by research (Boegueva *et al.,* 2017, Dagevos &Voordouw, 2013).

Economic policy instruments such as subsidies or taxes have been used to influence consumer choice via economic incentives and have shown to be particularly effective at driving dietary change, at least in developed countries (Dallongeville *et al.,* 2010; Capacci *et al.,* 2011; Mytton & Clarke, 2012; Thow *et al.,* 2014; Whitley *et al.,* 2018). Regulatory standards, in turn, prescribe what may be sold to consumers. However, the use of such policy instruments in the food sector has for the most part been restricted to the case of age-related prohibitions on the purchase of tobacco or alcohol (also see 6.4).

However, while the political *Zeitgeist* has favored informational policy tools, they often lack effectiveness. Studies have identified the prevalence of an attitude – action gap, and showed that structural constraints, such as information asymmetries and overflow as well as restrictions on time and other relevant resources by consumers, have prevented informational policy instruments from achieving major changes in food consumption patterns (Fuchs *et al.,* 2016; Horne, 2009). Among private certification schemes, those with the largest market shares often have little actual impact on the sustainability characteristics of a food product, as they tend to emphasize documentation rather than performance or fail to tackle the most impactful aspects of food production, distribution and consumption (Fuchs & Boll, 2012; Kalfagianni & Fuchs, 2015). Simultaneously, studies inquiring into the drivers of meat consumption have highlighted its promotion via advertising and media images that transport images of identity (especially masculinity, but also national and cultural identity) as well as artificially low meat prices (Bogueva *et al.,* 2017).

Thus, policy efforts to improve the sustainability of food consumption in general, and reduce animal protein consumption in particular, would require a policy mix reaching far beyond the (nudging of the) individual consumer (Fuchs *et al.,* 2013, 2016; Glanz & Mullis, 1988; Wolf & Schönherr, 2011). Such policies would need to focus on regulating the advertising of animal products, as well as sources of low meat prices, among others through lowering subsidies and enhancing (implementation of) animal welfare, labor and environmental standards. Simultaneously, policies could support (elements of) alternative food systems such as community-supported agriculture and different forms of farmers markets (Hinrichs & Lyson, 2007). Altering current dietary trajectories should not compromise the needs of low-income populations and of IPLCs and will face significant cultural and psychological barriers (Kuhnlein *et al.,* 2006; Whitley *et al.,* 2018).

Reducing food waste

Food waste currently runs at ~30-40% of all food production in developing and developed countries alike (Gustavsson *et al.,* 2011; Bond *et al.,* 2013; FAO, 2015, 2017; Bellemare *et al.,* 2017). Causes and hence possible solutions differ geographically, and they include more effective pest control (Oerke, 2006; Oliveira *et al.,* 2014), improved food distribution and better food storage in developing regions (Sheahan & Barrett, 2017), and consumer education (Kallbekken & Saelen, 2013; Aschemann-Witzel *et al.,* 2017; Young *et al.,* 2017) and less wasteful marketing practices in developed countries (Garrone *et al.,* 2014; Halloran *et al.,* 2014; Rezaei & Liu, 2017). Some countries, such as Japan, South Korea, Taiwan and Thailand have established operating systems that safely recycle more than one-third of their food waste as animal feed (Menikpura *et al.,* 2013; zu Ermgassen *et al.,* 2016; Salemdeeb *et al.,* 2017). However, several studies suggest an upper bound to feasible reduction in food waste of around 50% (Parfitt *et al.,* 2010; Bajzelj *et al.,* 2014; Odegard & van der Voet, 2014). Cutting food waste will thus require substantial changes in food supply chains and business models (Parfitt *et al.,* 2010; Papagyropoulou *et al.,* 2014; Aschemann-Witzel *et al.,* 2015; Roodhuyzen *et al.,* 2017).

Improving food distribution and localizing food systems

Localization of food systems is advocated by research (Hines, 2000) and by social movements, and has entered policy making at various levels (see e.g., the EU Regulation 1305/2013 on support for rural development or city-level food policies such as in Toronto or Manchester) emphasizing territoriality and sovereignty in food production and consumption. The major arguments supporting short food supply chains (SFSCs), beyond their socio-economic impacts such as revitalization of rural areas and local cultures (Brunori *et al.,* 2016; Schmitt *et al.,* 2017) are their potential to enhance food security and decrease food miles, the latter one addressing land-use change (less physical infrastructure for transportation), climate change (lower CO_2 emissions due to less transportation) and energy use (Mundler & Rumpus, 2012). However, the shortcomings of the local scale are also mentioned in literature, acknowledging that local is not necessarily better in terms of ecological sustainability, health, social justice etc. (Born & Purcell, 2006; Brunori *et al.,* 2016; Recanati *et al.,* 2016; Schmitt *et al.,* 2017). Evidence shows that the ecological impacts of SFSCs can be diverse, depending on the product type, the farming system (Rothwell *et al.,* 2016), the manner of transportation/logistics (Mundler & Rumpus, 2012; Nemecek *et al.,* 2016), the natural resources available locally and the actual social (Recanati *et al.,* 2016), economic and policy context (Leventon & Laudan, 2017).

Positive environmental impacts of SFSCs can be improved if the localization of agricultural production is coupled with: i) closing the loops between production, consumption and waste management (Benis & Ferrão, 2017; Sala *et al.,* 2017) (see also the section on circular economy in

6.4), ii) urban planning (integrating agriculture into the management of urban systems) (Barthel & Isendahl, 2013) through novel technological solutions that enable sustainable but more intensive food production (e.g., vertical gardens) (see also 6.3.5), iii) alternative food distribution options (e.g. social supermarkets or food banks) (Michelini *et al.,* 2018), iv) dietary changes as discussed below (Benis & Ferrão, 2017), and v) novel governance solutions across the food chain that enable more direct engagement of local communities in food production (Sonnino, 2017) and the (re)connection of various types of producers and consumers (Mount, 2012).

Expanding food market transparency and price stability

Food price increases during the 2007-08 world financial crisis resulted in severe impacts on the quality of life in many countries (Ivanic & Martin, 2008; Bellemare, 2015), leading many to assert that policies to increase food market transparency might lead to less volatility (Clapp, 2009; Minot, 2014). Policy responses to price increases have included reductions on food taxes and import tariffs, and increasing subsidies and food-based safety nets, although there is mixed evidence on which policies have been most effective in supporting poor populations (Wooden & Zama, 2010), indicating that social targeting is needed in combination with food support programs.

Public food procurement policies can also play a role in stabilizing price support for farmers. In Brazil, where government expenditures represent 20% of the GDP, two initiatives of public procurement of around US$300 million in expenditures are innovating to merge social and environmental targets. The Food Acquisition Program (created in 2003) and the National Program of School Feeding (created in 2009) have the purpose of: (i) providing healthy and balanced food respecting the culture, values and eating habits, especially for populations in socioeconomic vulnerability, and (ii) supporting the sustainable development of smallholding agriculture by incentives for producing local and seasonal food (Brazil, 2017). While the impact of these programs requires further evaluation, their goals to acquire locally produced food for school consumption while encouraging small-scale agricultural economies can be applicable in different contexts.

6.3.2.2 Sustainably managing multifunctional forests

Expanding and improving community-based forest management and co-management

Community-based forest management has emerged as a promising forest management alternative to state-controlled forest management (Charnley & Poe, 2007; Flint *et al.,* 2008; Krott *et al.,* 2014; Paudyal *et al.,* 2017). Almost one third of the forests in the Global South are now managed by IPLCs **(Figure 6.2)**, more than twice the share of protected areas (Chape *et al.,* 2005; RRI, 2014; Blackman *et al.,* 2017). Global trends towards decentralized management of forests, articulated through the active recognition of IPLCs rights to self-governance, have substantially improved the quality of life of forest-dependent communities, by providing them with greater livelihood benefits (Agrawal *et al.,* 2008; Gautam *et al.,* 2004; Larson & Soto, 2008; Phelps *et al.,* 2010; Duchelle *et al.,* 2014; RRI, 2014, 2016; Lawler & Bullock, 2017) including capital formation, governance reform, community empowerment and societal change (Pokharel *et al.,* 2007, 2015). Expanding and improving of community-based forest management have provided substantial opportunities for the conservation of forest ecosystems (Ostrom & Nagendra, 2006; Chazdon, 2008; Sandbrook *et al.,* 2010; Porter-Bolland *et al.,* 2012; Naughton-Treves & Wendland, 2014; van der Ploeg *et al.,* 2016; Asner *et al.,* 2017; Robinson *et al.,* 2017; Stickler *et al.,* 2017).

Many countries in Asia, such as the Philippines, Vietnam, Indonesia and Thailand have put forward new organizations, authorities and bottom-up approaches to promote community-based approaches to forest management (Sato, 2003; Poffenberger, 2006; Salam *et al.,* 2006; Sunderlin, 2006; Sikor & Tan, 2011), in the light of growing evidence of their effectiveness at contributing to poverty reduction (Ostrom, 1990; Brown *et al.,* 2003; Gautam *et al.,* 2004; Gilmour *et al.,* 2004; Gautam and Shivakoti, 2005; Sunderlin, 2006). These large areas managed by IPLCs do not usually attract financial and other resources akin to that provided for government-managed forest and protected areas. Moreover, there have been challenges in ensuring that communities have the right to benefit from co-management arrangements, such as from the sale of timber (Gritten *et al.,* 2015) and ensuring that IPLCs do not suffer from community forestry arrangements (such as in loss of food security or access to resources) (Sikor & Tan, 2011; Tuan *et al.,* 2017).

Forest titling programs have improved inclusion of settlers and secured alienation rights (Nelson *et al.,* 2001; Ostrom *et al.,* 2002; Pagdee *et al.,* 2006; Jacoby & Minten, 2007; Riggs *et al.,* 2016). However, forest tenure may not change management patterns without supporting the customary institutions of IPLCs that enforce exclusion rules and legitimize claims to them (Place & Otsuka, 2001; Ojha *et al.,* 2009; Kerekes & Williamson, 2010; Gabay & Alam, 2017).

Co-management of forest resources between the state and IPLCs, as well as other stakeholders, has also been promoted as an alternative to centralized governance approaches to achieve socio-economic and environmental objectives in developing countries (Carter & Gronow, 2005;

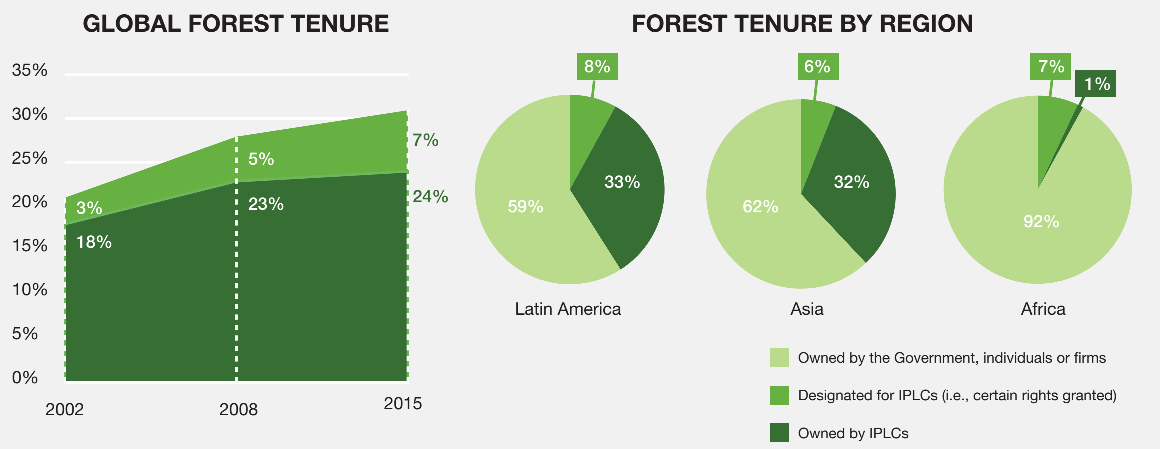

Figure 6 2 **Global patterns of forest owned by and designated for IPLCs.**
Source: RRI (2016).

Kothari *et al.,* 2013; Akamani & Hall, 2015). As forests are common-pool resources from which the exclusion of potential users is difficult, achieving sustainable forest management can be regarded a collective responsibility, especially in developing countries where the government has limited capacity to implement appropriate forest policy and needs support of diverse stakeholders (Sikor, 2006; Ostrom, 2010; Pokharel *et al.,* 2015). In the above context, collaborative governance is an appealing arrangement for sustainable forest management because of its potential to combine strengths of different management approaches and stakeholders (Carter & Gronow, 2005; Fernández-Giménez *et al.,* 2008).

Improving policies relating to PES and REDD+

There has been a rapid expansion in the number of payments for ecosystem services (PES) schemes and projects globally over the past 20 years, and many decision makers, from governments to NGOs, are considering either initial experimentation or continued expansion of PES. There is a great diversity of institutional configurations in PES arrangements, many of which involve a strong role of the state (McElwee, 2012; Shapiro-Garza, 2013). However, the effectiveness of PES approaches is currently unknown, namely because they are interpreted and implemented in many different ways (Borner *et al.,* 2017; Salzman *et al.,* 2018). Overall, the literature indicates that PES approaches are not a panacea (Muradian *et al.,* 2013), due to high preparation and transaction costs, uneven power relations, and distribution of benefits (Porras *et al.,* 2012; Salzman *et al.,* 2018; Berbés-Blásquez, 2016; Cáceres *et al.,* 2016; Van Hecken *et al.,* 2017). In other words, the performance of PES depends not just on economic incentives but also on other factors like motivations and environmental values (Hack, 2010; Hendrickson & Corbera, 2015; Grillos, 2017). Lessons learned from the literature on these economic financing instruments for conservation include the need to have in place strong regulatory frameworks; have clear metrics and indicators; have motivated buyers and sellers of services; recognize pluralistic value systems alongside financial considerations; acknowledge the importance of distributional impacts when designing economic instruments; and recognize that economic approaches are not a panacea (Ezzine-de-Blas *et al.,* 2016; Robalino & Pfaff, 2013; Pascual *et al.,* 2017; Hack, 2010; Hendrickson & Corbera, 2015; Grillos, 2017; van Hecken *et al.,* 2017; Salzman *et al.,* 2018; see also section 6.3.4.5 on watershed PES)

One important PES-like initiative is REDD+ (Reducing Emissions from Deforestation and forest Degradation), part of the negotiations under the UNFCCC since 2005 as a climate mitigation strategy to compensate developing countries for reducing GHG emissions from deforestation and forest degradation. REDD+ also aims to contribute to poverty alleviation of smallholders (through sale of carbon credits or direct forest products) and biodiversity conservation. Carbon forestry projects have expanded particularly rapidly in Latin America (Osborne, 2011; Corbera & Brown, 2010; Rival, 2013) and Africa (Namirembe *et al.,* 2014). However, the literature is currently mixed on the success rates of forest carbon projects in general and REDD+ has faced a number of challenges. These include a lack of a strong financial mechanism to ensure sufficient funding and demand for credits (Turnhout *et al.,* 2017), the high costs involved in setting up REDD+ projects (Luttrell *et al.,* 2016; Bottazzi *et al.,* 2013; Visseren-Hamakers *et al.,* 2012a), meeting the technical requirements of REDD+ (Turnhout *et al.,* 2017; Cerbu *et al.,* 2013) and REDD+'s ability to deliver non-carbon benefits such as biodiversity conservation (Hall *et al.,* 2012; Venter *et al.,* 2013; Duque *et al.,* 2014; Murray *et al.,* 2015) and social livelihoods (Atela *et al.,* 2015; Boyd *et al.,* 2007; Reynolds, 2012; Caplow *et al.,* 2011; Lawlor *et al.,* 2013). REDD+ has also been observed to contribute to a recentralization of forest governance by bringing forests under renewed forms of government control, with potentially negative consequences for nature, NCP and GQL (Ribot *et al.,* 2006; Phelps *et al.,* 2010; Sunderlin *et al.,* 2014; Duchelle *et al.,* 2014; Vijge & Gupta, 2014; Abidin 2015).

The future of REDD+ depends on its ability to safeguard against negative side effects of REDD+ and ensure that forests continue to deliver noncarbon benefits (Chhatre *et al.,* 2012; Visseren-Hamakers *et al.,* 2012b; Tacconi *et al.,* 2013; Luttrell *et al.,* 2013, Ojea *et al.,* 2015). As part of this, REDD+ will need to be inclusive of multiple values and perspectives, including historical, cultural and spiritual values (Gupta *et al.,* 2012; Brugnach *et al.,* 2014). This will require adequate formal arrangements for the participation of IPLCs. This involvement is crucial, since IPLCs control substantial areas of tropical forests (Anon, 2009; Bluffstone *et al.,* 2013). However, arrangements for participation by IPLCs in REDD+ policies are not clear in most country readiness plans for REDD+, despite safeguard guidance from UNFCCC (Ehara *et al.,* 2014), and participation has generally been weak in pilot activities, with many communities only consulted, rather than being involved in a systematic manner in all aspects of REDD+ planning (Hall, 2012; Brown, 2013). There is evidence that projects where IPLCs have been included from the beginning are stronger (Chernela, 2014). There is also potential for inclusion of IPLCs in community-based carbon monitoring, which has proven accurate and low cost (Danielsen *et al.,* 2013; Pratihast *et al.,* 2013; Brofeldt *et al.,* 2014; McCall *et al.,* 2016). See Supplementary Materials 6.2.3 for a detailed discussion on PES and REDD+.

Supporting Reduced Impact Logging (RIL)

More responsible logging practices, such as Reduced Impact Logging (RIL), are options to avoid deforestation and forest degradation. RIL, which involves close planning and control of harvesting operations, has increased in importance in the past decades. Such logging practices lower the ecological impacts of logging, especially on biodiversity (Bicknell *et al.,* 2017; Chaudhary *et al.,* 2016; Martin *et al.,* 2015). For example, in a study in East Kalimantan in Indonesia, application of RIL techniques have been found resulting in nearly half (36 vs 60 trees per ha) of collateral damage of trees as compared to the conventional harvesting methods (Sist, 2000). RIL techniques along with postharvest silvicultural treatments have also been found effective in enhancing canopy tree growth and regeneration and controlling invasion by alien and undesirable species (Campanello *et al.,* 2009). Moreover, improved logging practices in tropical forests can substantially reduce forest carbon loss and enhance retention (Putz *et al.,* 2008).

Promoting and improving forest certification

Forest certification, an economic instrument introduced in the early 1990s to improve forest management, can help address the concerns of deforestation and forest degradation and promote conservation of biological diversity especially in the tropics by promoting sustainable forest management and establishing deforestation-free supply chains (Rametsteiner & Simula, 2003; Auld & Gulbrandsen, 2008; Damette & Delacote, 2011). For instance, certification has been found to have positive impacts in terms of ecological outcomes (forest structure, regeneration, and lower fire incidences) (Kalonga *et al.,* 2015; Pena-Claros *et al.,* 2009) and biodiversity conservation in some places (Van Kuijk *et al.,* 2009; Kalonga *et al.,* 2016). Positive social impacts, such as better working and living conditions, active local institutions for discussions among the forestry company and local communities, and benefit sharing have also been documented (Cubbage *et al.,* 2010; Cerutti *et al.,* 2014; Burivalova *et al.,* 2016). There has also been criticism of different certification schemes, and forest certification more generally, among others on the fact that most certified forests are in the global North, instead of the South (Rametsteiner & Simula, 2003), in part due to the technical and financial demands for becoming certified can represent a hurdle for small and medium-sized enterprises in the South. For instance, current certification schemes tend to favor large forestry operations and do not directly translate to smaller operations. While there is still limited evidence of the impacts of different forest certification schemes (Visseren-Hamakers & Pattberg, 2013), improved assessment practices are suggesting ways forward (van de Ven and Cashore, 2018).

Controlling illegal logging

Illegal logging, which can be viewed as a symptom of failure of governance and law enforcement, is a major problem in achieving sustainable forest management in many countries, particularly forest-rich developing countries (Brack & Buckrell, 2011). Forest dependent poor people are the most harmed by illegal logging while powerful economic groups benefit the most from it (ODI, 2004). International trade in illegally logged timber is an important factor associated with this problem (Brack & Buckrell, 2011). In recent years, however, consumer countries have been paying increasing attention to trade in illegal timber and have taken different measures to exclude illegally produced timber from the market. The European Union's Action Plan for Forest Law Enforcement, Governance and Trade (FLEGT), published in 2003, is an example of such measures. The FLEGT regulations and approaches have often been combined with improved management of concessions in countries participating in FLEGT through Voluntary Partnership Agreements with the EU (Tegegne *et al.*, 2014). Apart from the European Union's Timber Regulation 995/2010, some other countries, including Australia, Indonesia, Japan and USA, have their own law to control illegal logging (Hoare, 2015).

Monitoring and regulating forest use

The development and availability of transparent forest monitoring data is a major step to establish and improve the forest sector (Fuller, 2006). By identifying the extent of deforestation on a regular basis, decision makers have the option to coordinate actions, prioritize areas and develop policies to reduce forest losses. In the Brazilian Amazon, where the deforestation was substantially reduced from 2004 to 2017 (INPE, 2017), the understanding of forest change patterns was essential to allocate public resources and to provide the first reaction to the illegal processes that were leading to deforestation in that region. The monitoring systems have been improved to the point of offering daily real-time data, constituting one of the most important tools for the fight against deforestation in Brazil (Nepstad *et al.,* 2014; Assunção *et al.,* 2015). Also, global initiatives like the Global Forest Watch are supporting national and sub-national governments to implement national law (as in the case of the law Nr 26331on "Minimum Standards of Environmental Protection of Native Forests" in Argentina), as well as civil society and private sector engagement in forest monitoring and conservation (FAO, 2015; GFW, 2017). Reforestation projects have contributed to reversing the deforestation trend and increasing forest cover in some countries (Supplementary Materials 6.2.3). Especially REDD+ and PES schemes have contributed to expand reforestation and afforestation projects in recent years (Carnus *et al.,* 2006; Madsen *et al.,* 2010). REDD+ projects have expanded particularly rapidly in Latin America (Osborne, 2011; Corbera & Brown, 2010; Corbera & Brown, 2008) and Africa (Jindal *et al.,* 2012; Namirembe *et al.,* 2014).

Land tenure recognition and cadastral registers are tools that contribute to the implementation of regulations aimed to protect forest and support reforestation actions. For instance, the Rural Environmental Registry (CAR) in Brazil records and analyses information about land use and environmental compliance in all private properties. CAR registration is mandatory and linked to official credit support, environmental licensing and regularization. It is also used in voluntary agreements for trading agricultural products and facilitating the process of forest restoration to reach legal compliance (Soares-Filho *et al.,* 2014; Servicio Florestal Brasileiro, 2016). The implementation of the CAR system in Brazil is an example of confronting the simultaneous challenges of monitoring, enforcement and compliance, and reconciling forest and water conservation and other production sectors, particularly agriculture.

Forest concessions can also be an option to protect forest cover and regulate use, reducing the pressure to replace the natural vegetation with other land uses. Concessions give the holder rights, including harvesting timber (or other forest products) and use of forest services (e.g. tourism, watershed protection) (Gray, 2002). Concessions, if properly governed, can be an important instrument to provide economic value to forests and reduce the pressure to replace the natural vegetation with other land uses around the world. Besides employment and revenue creation, forest concessions may reinforce the presence of the state and improve the rights over land tenure (FAO, 2015). Concessions are also a good governance tool for the state, considering the establishment of conditions and compensation, such as the development of local services (schools, medical assistance, security) and infrastructure (water supply, transport, roads, bridges). This instrument can be applied not only by entrepreneurs and companies, but also by IPLCs with different land tenure regimes (van Hensbergen, 2016). Poorly governed concession schemes, however, can drive deforestation and marginalize local communities. Governments can enhance the contributions of forest concessions by requiring participatory planning, long-term sustainable forest management, and control of illegal logging.

Problems of forest concessions in tropical countries are related to weak local governance, poor level of compliance, difficulties with monitoring and traceability systems, low technical capacity of managing the forest, and insufficient rewards for sustainable forest management in the global timber market (Azevedo-Ramos *et al.,* 2015; van Hensbergen, 2016; Segura-Warnholtz, 2017). Therefore, forest concessions are often regarded drivers of forest degradation (PROFOR, 2017). Corruption in attaining timber concessions is another problem associated with this instrument, especially in developing countries. There are initiatives of implementing monitoring and traceability systems, but it is important to manage the bureaucracy and additional transaction costs that may deter potential investors (Azevedo-Ramos *et al.,* 2015).

6.3.2.3 Protecting nature within and outside of protected areas

Improving management of protected areas

There is a large literature that has evaluated the performance of protected areas (PAs) in halting biodiversity loss and securing ecosystem services into the future, showing mostly positive (albeit moderate) conservation outcomes (Carranza *et al.,* 2014; Barnes *et al.,* 2016; Eklund *et al.,* 2016; Gray *et al.,* 2016). However, research also points to substantial shortfalls in PA effectiveness around the world (Laurance *et al.,* 2012; Guidetti *et al.,* 2014; Watson *et al.,* 2014; Geldmann *et al.,* 2015, 2018; Schulze *et al.,* 2018). Poor PA performance is attributed to management deficiencies related to inadequate resources and weak governance. It also includes low compliance due to inhibited local access to important resources (Stoll-Kleemann, 2010; Bennett & Dearden, 2014; Bruner *et al.,* 2001; Eklund & Cabeza, 2016; Leverington *et al.,* 2010; Watson *et al.,* & Hockings, 2014). Evidence shows that improving PA effectiveness depends on enforcing sound management (Juffe-Bignoli *et al.,* 2014), monitoring (Schulze *et al.,* 2018) and adequate resourcing (McCarthy *et al.,* 2012). Using robust methods, such as those available via the global Protected Areas Management Effectiveness (PAME) initiative, controlling potential bias, and integrating data on ecological outcomes (e.g. temporal and spatial counterfactual analysis) and social indicators could make the assessment of PA effectiveness more systematic and comparable across spatial and temporal scales, addressing the needs of different decision makers more effectively (Coad *et al.,* 2015; Eklund *et al.,* 2016; Stoll-Kleemann, 2010; Watson *et al.,* 2016) for all decision makers.

PAs generate multiple benefits to both local and distant populations (Chan *et al.,* 2006; Ceausu *et al.,* 2015; Egoh *et al.,* 2011; Larsen *et al.,* 2012; Schröter *et al.,* 2014a), and provide fundamental contributions such as protecting watersheds, buffering extreme events, regulating local climate, harboring biodiversity, and providing spaces of emotional, social and spiritual fulfilment. Protected areas and these multiple contributions also have associated costs in limiting and regulating land uses and forms of access to resources (Birner & Wittmer, 2004; Holzkamper & Seppelt, 2007; Wätzold *et al.,* 2010; Wätzold & Schwerdtner, 2004; Nalle *et al.,* 2004). Balancing the benefits and costs of PAs across different stakeholders can increase the management effectiveness of PAs (see also Supplementary Materials 6.2.4). Options include co-management governance regimes (i.e. sustainable-use PAs), which engage communities in maintaining cultural and livelihood benefits (Oldekop *et al.,* 2016), and jointly consider approaches to mitigating conflicts and managing trade-offs. PA effectiveness can also be enhanced by supporting local households to establish or find alternative livelihood and income options (i.e., improving options and capabilities; Neudert *et al.,* 2017), supporting benefit-sharing mechanisms that eliminate inequalities (Swemmer *et al.,* 2017) and securing the availability of financial resources to support these measures for a sufficiently long period to ensure sustainability (Wätzold *et al.,* 2010).

Improving spatial and functional connectivity of PAs

The functionality of PA networks cannot be maintained when the habitat area is too small and fragmented, and when the landscape beyond PA boundaries is inhospitable (Bengtsson *et al.,* 2003). PAs then become islands of biological conservation (Bauer & Van Der Merwe, 2004; Crooks *et al.,* 2011; Seiferling *et al.,* 2012; Barber *et al.,* 2014; Wegmann *et al.,* 2014) threatening the long-term viability of their biodiversity, especially many wildlife populations (DeFries *et al.,* 2005; Newmark, 2008; Riordan *et al.,* 2015). There are also significant geographic and ecological biases in the representation of habitats and ecosystems in PAs (e.g., Pressey *et al.,* 2003; Joppa & Pfaff, 2009, Butchart *et al.,* 2012, 2015), which result in unplanned assemblages of PAs confined to economically unproductive areas (Scott *et al.,* 2001; Evans, 2012), with little ecological relevance (Opermanis *et al.,* 2012), which ultimately compromise their overall conservation potential (Watson *et al.,* 2014).

Options to address these challenges include several policy support tools for (spatial) conservation prioritization to inform where to establish new PAs so that more biodiversity is conserved in a cost-effective way, accounting for multiple competing sea- or land uses and socioeconomic factors (e.g., Dobrovolski *et al.,* 2014; Forest *et al.,* 2007; Isaac *et al.,* 2007; Montesino Pouzols *et al.,* 2014; Nin *et al.,* 2016; Di Minin *et al.,* 2017). Spatial conservation planning can be a useful tool for enhancing landscape connectivity, maximizing the ecological representation of PA networks and safeguarding Key Biodiversity Areas (Edgar *et al.,* 2008; Krosby *et al.,* 2010, 2015; Dawson *et al.,* 2011; Cabeza, 2013; Dickson *et al.,* 2014, 2017; Kukkala *et al.,* 2016; Watson *et al.,* 2016; Saura *et al.,* 2018). Research has estimated that only 19.2% of the ~15,000 Key Biodiversity Areas identified around the world are fully protected, and that the proportion of the PAs comprising these areas is decreasing over time (Butchart *et al.,* 2012; UNEP-WCMC & IUCN, 2016). Therefore, protected areas are being disproportionately established in areas that are suboptimal from a biodiversity conservation point of view (Butchart *et al.,* 2012, 2015). Shifting PA establishment to focus on Key Biodiversity Areas is thus an important policy priority to reverse extinction risk trends.

Building on the expansion of PAs under Aichi Biodiversity Target 11, the next phase of global biodiversity targets offers an excellent opportunity to correct some of the geographic biases of establishing PAs in recent decades, often based on local and opportunistic criteria (Pressey *et al.,* 2003; Joppa & Pfaff, 2009; Lewis *et al.,* 2017). Especially the conservation of world's old-growth forests can be addressed in Multilateral Environmental Agreements, as targets for PA expansion (e.g., Watson *et al.,* 2018). Expanding PAs requires managing trade-offs among societal objectives, and improvement can be achieved with global coordination (DeFries *et al.,* 2007; Polasky *et al.,* 2008; Faith, 2011; Venter *et al.,* 2014) and consultation of different stakeholders.

Improving transboundary PA and landscape governance

Options to enhance PA effectiveness also need to address conservation planning and management at broader geographic scales (van Teeffelen *et al.,* 2006; Le Saout *et al.,* 2013; Kukkala *et al.,* 2016). Transboundary conservation planning is essential to improve the global status of biodiversity (Erg *et al.,* 2012; Pendoley *et al.,* 2014; Dallimer & Strange, 2014; Lambertucci *et al.,* 2014), particularly for wide-ranging species that cannot be conserved within political boundaries, such as large carnivores (Wikramanayake *et al.,* 2011; Wegmann *et al.,* 2014; Santini *et al.,* 2016; Di Minin *et al.,* 2017), species that migrate (Flesch *et al.,* 2010; Runge *et al.,* 2015; Owens, 2016) and species that might shift their range in response to climate change (Wiens *et al.,* 2011; Zimbres *et al.,* 2012; Johnston *et al.,* 2013; Pavón-Jordán *et al.,* 2015).

Research shows that setting conservation targets in a spatially coherent manner beyond national borders is vital for improving the effectiveness of PA networks (van Teeffelen *et al.,* 2015; Wegmann *et al.,* 2014). Different works have demonstrated a major efficiency gap between national and global conservation priorities, finding that if each country sets its own conservation priorities without international coordination, more biodiversity is lost than if conservation decision-making is done through international partnerships and globally coordinated efforts (Montesino-Pouzols *et al.,* 2014; Santini *et al.,* 2016). The European Union's Natura 2000 network of PAs provides an illustrative example of joint initiatives crossing political and national boundaries. With more than 27,000 sites across all EU countries, covering over 18% of the EU's land area and almost 6% of its marine environments, Natura 2000 is the most expansive coordinated network of PAs in the world (Milieu *et al.,* 2016). It is the cornerstone of the EU's Biodiversity Strategy to 2020, and one of the largest policy efforts in conserving biodiversity irrespective of national and political boundaries. A plethora of research studies has evidenced the overall ecological effectiveness of Natura 2000, with a special emphasis on terrestrial vertebrates and threatened habitats (Gruber *et al.,* 2012; Pellissier *et al.,* 2013; Kolecek *et al.,* 2014; Sanderson *et al.,* 2016; Beresford *et al.,* 2016; Milieu *et al.,* 2016). The Greater Mekong Subregion Biodiversity Conservation Corridors Project or the Mesoamerican Biological Corridor are also key initiatives illustrating the importance of transboundary conservation planning at the landscape level (ADB, 2011; Mendoza *et al.,* 2013; Crespin & García-Villalta, 2014). Policy options to promote transformative change towards sustainability in the Arctic include the application of new, multi-sector frameworks for integrated ecosystem management (Pinsky *et al.,* 2018), the establishment of a circumpolar network of Protected Areas (Fredrikson, 2015) and the proposal for the creation of a global Arctic sanctuary in the high seas (European Parliament, 2014; Greenpeace, 2014).

Recognizing management by IPLCs and OECMs

The conservation of a substantial proportion of the world's biodiversity and NCP largely depends on the customary institutions and management systems of IPLCs (Maffi, 2005; Gorenflo *et al.,* 2012; Gavin *et al.,* 2015; Renwick *et al.,* 2017; Garnett *et al.,* 2018). Evidence suggests that IPLCs are able to develop robust institutions to govern their land- and seascapes in ways that align with biodiversity conservation (ICC, 2008, 2010; Stevens *et al.,* 2014; Ens *et al.,* 2015, 2016; Trauernicht *et al.,* 2015; Blackman *et al.,* 2017; Schleicher *et al.,* 2017). These customary institutions and management systems are based on locally-grounded knowledge and encoded in complex cultural practices, relational values, usufruct systems, spiritual beliefs, kinship-oriented philosophies, and principles of stewardship ethics (Berkes *et al.,* 2000; Bird, 2011; Gammage, 2011; Kohn, 2013; Walsh *et al.,* 2013; Trauernicht *et al.,* 2015; Gaudamus & Raymond-Yakoubian, 2015; Fernández-Llamazares *et al.,* 2016; Renwick *et al.,* 2017).

Formal recognition of IPLC rights over their territories can be an effective means to significantly slow habitat loss (Nepstad *et al.,* 2006; Soares-Filho *et al.,* 2010; Ricketts *et al.,* 2010; Porter-Bolland *et al.,* 2012; Nolte *et al.,* 2013; Paneque-Gálvez *et al.,* 2013; Ceddia *et al.,* 2015; Blackman *et al.,* 2017). The growing recognition of governance diversity in global environmental policy offers numerous opportunities for sound management of nature and its contributions to the larger society (Berkes, 2009; Kothari *et al.,* 2012; Ruiz-Mallén & Corbera, 2013; Nilsson *et al.,* 2016), while improving the quality of life of IPLCs, including addressing some of the human rights violations associated with the establishment and governance of some PAs (e.g., Brockington & Igoe, 2006; Goldman, 2011; Kohler & Brondizio, 2016). Certain strict PAs have induced displacements and exclusion of IPLCs (West *et al.,* 2006; Mascia & Claus, 2008; Curran *et al.,* 2009; Agrawal & Redford, 2009; Brockington & Wilkie, 2015), undermining food sovereignty (Golden *et al.,* 2011; Foale *et al.,* 2013; Nakamura & Hanazaki, 2016; Sylvester *et al.,* 2016) and contributing to psychological distress and trauma (Dowie, 2009; Zahran *et al.,* 2015; Snodgrass *et al.,* 2016).

A crucial breakthrough in conservation paradigms over the last decades has been the emergence and growing awareness of a number of IPLC-centred designations to conservation, including co-management regimes, community-based conservation areas, integrated conservation and development projects, sacred natural sites, Indigenous Community Conserved Areas (ICCAs), and biocultural approaches to conservation (e.g., Berkes, 2004, 2007, 2009; Folke *et al.,* 2005; Armitage *et al.,* 2007;

Kothari *et al.,* 2013; Brooks *et al.,* 2013; Gavin *et al.,* 2015; Alexander *et al.,* 2016; Berdej & Armitage, 2016; Sterling *et al.,* 2017). Many of these approaches will contribute a substantial share of the world's "Other Effective Area-Based Conservation Measures" (OECMs) such as proposed under Aichi Target 11 (Jonas *et al.,* 2014, 2017; Laffoley *et al.,* 2017; Garnett *et al.,* 2018).

Sacred natural sites, as a specific example of OECMs, are areas of land or water that have spiritual values to certain IPLCs (Thorley & Gunn, 2007; Ormsby, 2011). They contribute to the conservation of diverse habitats and species as well as traditional land use practices (Salick *et al.,* 2007; Metcalfe *et al.,* 2009; Gavin *et al.,* 2015; Samakov & Berkes, 2017). Their governing institutions are diverse, including informal norms, rules and taboos passed on by generations (Anthwal *et al.,* 2010; Bhagwat & Rutte, 2006b; Bobo *et al.,* 2015; Ya *et al.,* 2014), and are under increasing pressure from globalization (Bhagwat & Rutte, 2006; Virtanen, 2002; Domínguez & Benessaiah, 2015; Fernández-Llamazares *et al.,* 2018). Sacred natural sites have been combined with legal and economic instruments, often with controversial results (Bhagwat & Rutte, 2006b; Brandt *et al.,* 2015). Appropriate legal recognition of sacred natural sites has been deemed as a critical factor to ensure their effectiveness in conserving nature and NCP (Davies *et al.,* 2013; Smyth, 2015; Mwamidi *et al.,* 2018). Specific legal recognition of sacred natural sites builds on prior broader recognition of collective IPLC tenure rights and self-determination (Kothari, 2006; Berkes, 2009; Almeida, 2015; Borrini-Feyerabend & Hill, 2015). However, there is evidence that top-down forms of recognition, without consultation often undermine local initiative and grassroots action (Borrini-Feyerabend *et al.,* 2010; Kothari *et al.,* 2013). Best practice cases indicated that knowledge-sharing and mutual learning are key success factors when sacred sites are recognized as OECMs (Aerts *et al.,* 2016b; Irakiza *et al.,* 2016; Jonas *et al.,* 2018).

Addressing the Illegal Wildlife Trade (IWT)

Despite intense worldwide efforts, the Illegal Wildlife Trade (IWT) still represents a major threat to endangered species. Research shows the major strengths and weaknesses of efforts to address the IWT. CITES currently lacks a global enforcement agency to oversee compliance, which has been argued to compromise its overall effectiveness (Phelps *et al.,* 2010; Heinen & Chapagain, 2002; Oldfield, 2003; Zimmerman, 2003; Reeve, 2006; Toledo *et al.,* 2012; Challender *et al.,* 2015). Further, CITES enforcement within countries is often sporadic at best, with many developing countries lacking the knowledge and identification facilities to help control and report illegal trade (Zhang *et al.,* 2008; Shanee, 2012). The International Consortium on Combating Wildlife Crime (ICCWC) has helped in providing support to countries in the fields of policing, customs, prosecutions and the judiciary, (e.g., through the creation of the ICCWC Wildlife and Forest Crime Analytical Toolkit; UNODC, 2012) and informing IWT decision-making (Nellemann *et al.,* 2014; Sollund & Maher, 2015). In the meantime, research shows that intergovernmental initiatives at the regional level, such as the ASEAN Wildlife Enforcement Network, including 10 Southeast Asian countries, and EU-TWIX, an online forum and database on IWT patterns within the European Union, are also essential for assisting national law enforcement agencies in detecting and monitoring IWT across national borders (Rosen & Smith, 2010; Sollund & Maher, 2015). Civil society and NGO support, such as through TRAFFIC, has been essential for many countries to keep their mandatory reporting requirements for CITES up to date (Reeve, 2006).

Some studies are examining where resources could best be prioritized for improved protected area management and law enforcement, as well as to disrupt shipping routes of IWT (Kiringe *et al.,* 2007; Plumptre *et al.,* 2014; Ihwagi *et al.,* 2015; Patel *et al.,* 2015; Tulloch *et al.,* 2015; Lindsey *et al.,* 2017). Improving detection capacity for "invisible" wildlife trades, through improved data, capacity-building and implementation of innovative technologies such as DNA barcoding and stable isotope analysis, is often cited as a global priority for IWT control (Phelps *et al.,* 2010; Nijman & Nekaris, 2012; Phelps & Webb, 2015; Symes, 2017).

Prioritization of IWT in criminal justice systems has generally led to more effective law enforcement responses (Lowther *et al.,* 2002; Sollund & Maher, 2015; EIA, 2016; Jayanathan, 2016). Similarly, increases in anti-poaching patrols in protected areas generally leads to significant declines in levels of poaching (Dobson & Lynes, 2008; Jachmann, 2008; Fischer *et al.,* 2014; Critchlow *et al.,* 2016; Henson *et al.,* 2016; Moore *et al.,* 2017). Implementing measures to combat corruption among rangers, crime investigators and other relevant officials and civil servants, is also deemed critical to halt IWT (Smith & Walpole, 2005; Bennett, 2015; UNODC, 2016). Also, IPLCs are important allies in global efforts to combat IWT on the ground (Roe, 2011; MacMillan & Nguyen, 2013; Ihwagi *et al.,* 2015; Cooney *et al.,* 2016; Humber *et al.,* 2016; Benyei *et al.,* 2017; Biggs *et al.,* 2017; Massé *et al.,* 2017; Roe *et al.,* 2017), although they often suffer from blanket hunting bans established at local levels that do not discriminate between endangered and common animals (McElwee, 2012) as well as use of trade bans to address other threats such as climate change (Weber *et al.,* 2015). Similarly, both NGO and research presence have been shown to deter wildlife poaching, particularly in areas with minimal governmental surveillance (Hohman, 2007; Pusey *et al.,* 2007; Campbell *et al.,* 2011; N'Goran *et al.,* 2012; Laurance, 2013; Mohd-Azlan & Engkamat, 2013; Daut *et al.,* 2015; Piel *et al.,* 2015; Sollund & Maher, 2015; Tagg *et al.,* 2015).

Finally, well-targeted, species-specific and evidence-based demand reduction policy interventions for illegally-sourced wildlife and its products are also growing in scope and extent, on the understanding that legally-sourced products are managed sustainably based on CITES non-detriment findings, and harvested and traded in accordance with national and international laws (CITES, 2017; Moorhouse *et al.,* 2017). Social marketing strategies (e.g. discouraging rhino horn consumption in Vietnam through TV ads with celebrities) coupled with broad outreach and educational campaigns, are a common strategy to change consumer behaviour (Drury, 2009, 2011; Dutton *et al.,* 2011; Gratwicke *et al.,* 2008a; Veríssimo *et al.,* 2012; Challender & MacMillan, 2014; TRAFFIC, 2016; Truong *et al.,* 2016), although evidence on the effectiveness of such policies is still virtually lacking (MacMillan & Challender, 2014; Challender *et al.,* 2015). Regular online monitoring of e-commerce platforms, websites and social media offers substantial opportunities for the enforcement of IWT regulations (Izzo, 2010; Hansen *et al.,* 2012; Lavorgna, 2015; TRAFFIC, 2015).

Improving Sustainable Wildlife Management (SWM)

Sustainable Wildlife Management (SWM) is an essential tool to conserve wildlife while considering the socioeconomic needs of human populations, including IPLCs (Gillingham & Lee, 1999; Spiteri & Nepal, 2006; Pailler *et al.,* 2015; Riehl *et al.,* 2015; Campos-Silva & Peres, 2016) and the generation of multiple contributions to people (Holmlund & Hammer, 1999; Díaz *et al.,* 2005; Kremen *et al.,* 2007; Whelan *et al.,* 2008, 2015; Kunz *et al.,* 2011; Moleón *et al.,* 2014; Ripple *et al.,* 2014; Poufoun *et al.,* 2016). Several best practices in fostering SWM (e.g., mitigating human-wildlife conflicts) have emerged over the last decades (Brooks *et al.,* 2013; FAO, 2016; Nyhus, 2016), and the debate increasingly includes animal welfare aspects, among others under the heading of "compassionate conservation" (Bekoff, 2013).

Both *incentive-driven* and *financial compensation* schemes can contribute widely to nature conservation and benefit sharing with IPLCs and provide economic compensation for those bearing most of the costs of maintaining public benefits associated with biodiversity conservation (Naughton-Treves *et al.,* 2003; Maclennan *et al.,* 2009; Persson *et al.,* 2015; Dhungana *et al.,* 2016, Supplementary Materials 6.2.4). However, the effectiveness of wildlife compensation schemes in conserving nature and contributing to local quality of life varies (Boitani *et al.,* 2010; Ravenelle & Nyhus, 2017). Some works show that wildlife compensation schemes can reduce conflict (Zabel & Hom-Müller, 2008), reduce wildlife killings (Okello *et al.,* 2014) and recover wildlife populations (Persson *et al.,* 2015), particularly in contexts where IPLCs are facing acute subsistence needs or with wildlife that imposes disproportionate costs. However, several pitfalls and operational issues undermine the effectiveness of wildlife compensation payments mostly related to their administration, including crowding-out effects, unequal distribution of benefits, elite capture, corruption or leakage (e.g., Bulte & Rondeau, 2005; Ogra & Badola, 2008; Spiteri *et al.,* 2008; Agarwala *et al.,* 2010; Uphadyay, 2013; Anyango-Van Zwieten, *et al.*, 2015). Also, some authors have questioned their financial sustainability in the long-term (Nyhus *et al.,* 2003; Bulte & Rondeau, 2005; Swenson & Andrén, 2005; Bauer *et al.,* 2015). In general, research highlights that wildlife compensation schemes are not a silver-bullet solution, although they might be indeed valuable in certain contexts and under certain conditions (Haney, 2007; Dickmann *et al.,* 2011; Ravenelle & Nyhus, 2017). *Conservation performance payments*, conditional on specific conservation outcomes (e.g., bird breeding success), have been argued to partially address some of the operational challenges of incentives focusing on compensation for losses to predation (Zabel & Holm-Müller, 2008).

Nature-based tourism is another revenue-generating use of certain wildlife that can provide incentives for IPLCs to conserve biodiversity in appropriate contexts (Bookbinder *et al.,* 1998; Kiss, 2004; Hearne & Santos, 2005; Lindsey *et al.,* 2005; Lai & Nepal, 2006; Stronza, 2007; Osano *et al.,* 2013). IPLCs with economically viable ecotourism programs linked to wildlife are likely to steer SWM (Stem *et al.,* 2003; Krüger, 2005; Clements *et al.,* 2010; Mendoza-Ramos & Prideaux, 2017), but only when benefits are culturally-appropriate and equitably distributed (Bookbinder *et al.,* 1998; Naidoo & Adamowicz, 2005; He *et al.,* 2008), land tenure is secured (Charnley, 2005; Haller *et al.,* 2008; Bluwstein, 2017), the social and political justice aspirations of IPLCs are respected (Stronza & Gordillo, 2008; Coria & Calfucura, 2012), and the value conflicts introduced by tourism development are fully addressed (Lai & Nepal, 2006; Waylen *et al.,* 2010).

Although financial benefits to sustain SWM have often been prioritized (Tisdell, 2004; Ogra & Badola, 2008), incentives to engage IPLCs in SWM can also include education, empowerment and opportunities for capacity development (Nabane & Matzke, 1997; Brooks *et al.,* 2009), social services and infrastructure (Spiteri & Nepal, 2006), as well as devolution of IPLC rights to manage, and benefit from, wildlife conservation (Lindsey *et al.,* 2009; Western *et al.,* 2015; Nilsson *et al.,* 2016). Moreover, engaging women in SWM as direct beneficiaries and key stewards of wildlife can help bridging the agendas of gender equality and SWM, particularly within the framework of the SDG (Nabane & Matzke, 1997; Espinosa, 2010; Staples & Natcher, 2015; FAO, 2016; UNEP, 2016; Leisher *et al.,* 2016; Lelelit *et al.,* 2017). Gender mainstreaming approaches are crucial for the success of community-based SWM (Ogra, 2012; Meola, 2013; UNESCO, 2016; Davies *et al.,* 2018).

Manage invasive alien species through multiple policy instruments

There are more than 40 international legal instruments dealing with the issue of invasive alien species (IAS), including CITES and the Ramsar Convention on Wetlands, as well numerous national laws. However, there are many legal, institutional and social barriers to effective invasive species management, including information management challenges, resourcing, risk perception and lack of public support, and definitional and jurisdictional issues that can generate a lack of coherent, systemic and community-partnered approach to IAS management. This is particularly the case in urban and peri-urban areas where rapid urban growth and sprawl occurs (Martin *et al.,* 2016; Le Gal, 2017; Riley, 2012; Vane and Runhaar, 2016). Further, low economic incentives to engage private landowners can undermine the effectiveness of the frameworks for IAS management and biodiversity protection (Martin *et al.,* 2016). Developing and implementing IAS management strategies in collaboration with IPLCs has been suggested as an effective means to enhance local capacity to prevent, detect and eradicate IAS in areas inhabited or managed by IPLCs, although the evidence still lies on weak empirical footing, with only a few case-based studies available (e.g., Hall, 2009; Dobbs *et al.,* 2015). It is well established that social, political and economic values, as well as cultural worldviews have been shown to underlie the perception of IAS, as well as preferences over management options (O'Brien, 2006; Warren, 2007; Hall, 2009; Crowley *et al.,* 2017). In view of this, direct inclusion of IPLCs on deliberations over IAS management decisions can help to identify the most strategic and effective measures for IAS control, as well as to anticipate conflict and foster dialogue over different values in inclusive ways (Robinson *et al.,* 2005; Bhattacharyya *et al.,* 2014).

Potential solutions include treating IAS as a collective action problem rather than a private landowner problem (Martin *et al.,* 2016; Graham *et al.,* 2016; Graham, 2013; Howard *et al.,* 2016), implementing projects for removal of IAS through direct payments (Bax *et al.,* 2003; McAlpine at al., 2007; Rumlerova *et al.,* 2016; Brown *et al.,* 2016), through tax incentives combined with restoration work and tradeable permits (see examples in Supplementary Materials 6.2.4).

6.3.2.4 Expanding ecosystem restoration projects and policies

Ecological restoration is *the process of assisting the recovery of an ecosystem that has been degraded, damaged,* or destroyed (SER, 2004) and reforestation can have potential positive impacts to help ecosystems adjust to climate change, such as through restoring altered hydrological cycles, extending habitat for species threatened by climate change, or protecting coastal areas from storms and sea level rise (Locatelli *et al.,* 2015). For instance, the UN is committed to restoration through projects such as reforestation for carbon sequestration (e.g. REDD+) (Nellemann & Corcoran, 2010; Watson *et al.,* 2000; Munasinghe & Swart, 2005) or restoring wetlands for flood protection. There is wide agreement on the importance of expanding restoration efforts, including the CBD Aichi Target 15 that commits to restoration of at least 15% of degraded ecosystems by 2020, the European Union Biodiversity Strategy Target 2, and the Bonn Challenge to restore 150 and 350 million hectares of the world's deforested and degraded lands by 2020 and 2030, respectively. Restoration and reforestation of 12 million ha of forests by 2030 are also key elements of the implementation of the Brazilian Nationally Determined Commitments (NDC) of the Paris Agreement.

Restoration projects make use of both regulatory and market instruments in policy mixes, such as public financing, mitigation banking or offsetting, tax incentives, and performance bonds (Hallwood, 2006; Reiss *et al.,* 2009; Robertson, 2004; Ruhl *et al.,* 2009). Tax incentives for set-asides for restoration work, such as Landcare & Bushcare policies (in Australia), are farmer voluntary policies that encourage community-based strategic restoration projects (Compton and Beeton, 2012), including bush set-asides for recovery from grazing and grants to replant and fence off bushland. Farmers pay for at least half the restoration costs, which can be reclaimed through tax incentives (Abensperg-Traun *et al.,* 2004). The Working for Water Program in South Africa is an example of an approach that combines IAS removal and restoration through targeted employment and payments to poorer participants. The project has been credited with success in native vegetation species recovery (Beater *et al.,* 2008; van Wilgen & Wannenburgh, 2016) and increasing water yields (Le Maitre *et al.,* 2000, 2002; Dye & Jarmain, 2004). Lessons from the South Africa program include the need for continuous monitoring and frequent follow-up, the need to train personnel, and the need for active restoration (and replanting) of native tree species on cleared plots. Another national example of integrating restoration objectives into specific policies is that of the Rural Environmental Registry (CAR), which supports the implementation of the new Forest Law in Brazil (see section on Monitoring and regulating forest use above).

Contextual and historical legacies often shape restoration practices. Therefore, there is increasing recognition that restoration projects need to be seen as part of larger social-ecological systems (Dunham *et al.,* 2018; Zingraff-Hamed, 2017), also considering social goals in the planning, decision-making, implementation and success evaluation of such projects (Junker, 2008; Hallett *et al.,* 2013; Higgs, 2005; Burke & Mitchell, 2007; Woolsey *et al.,* 2005;

2007). It is for example increasingly recognised that it is beneficial to involve all relevant stakeholder groups to gain acceptance (Junker *et al.,* 2007) and to promote social and environmental learning (Pahl Wostl, 2006; Restore, 2013; Petts, 2006). One example is the 're-wilding' approach in the US (Swart *et al.,* 2001; Hall, 2010) to restore to pre-European settlement ecosystems, which contrasts with the cultural landscape approach in Germany (Westphal *et al.,* 2010). The importance of community culture and normative values in shaping social acceptance of restoration projects has often been neglected (Ostergren *et al.,* 2008; Waylen *et al.,* 2009), with acceptance depending on whether restoration builds upon the emotional or cultural attachments that communities have to a place or supports traditional patterns of use (Baker *et al.,* 2014; Buijs, 2009; Drenthen, 2009; Lejon, 2009; Shackelford *et al.,* 2013). Participation, such as through community reforestation, is seen to reduce the risk of conflict (Eden and Tunstall, 2006; Gobster and Barro, 2000; Higgs, 2003) and promises more equitable outcomes, such as access to ecosystem services. This opens restoration as a tool for poverty alleviation. However, there is a knowledge gap in defining measures for social-economic attributes, although this has recently received attention (Baker & Eckerberg, 2016). Overall, there is a need for more research into the realized social and economic outcomes or impacts of restoration (see Supplementary Materials 6.2.4).

Revitalizing ILK and restoring IPLC institutions

Evidence shows that indigenous and local knowledge (ILK) is rapidly changing and eroding in many parts of the world (Cox *et al.,* 2000; Brodt, 2001; Godoy *et al.,* 2005; Brosi *et al.,* 2007; Turner & Turner, 2008; Reyes-García *et al.,* 2007, 2013, 2014; Tang & Gavin, 2016; Aswani *et al.,* 2018). While ILK is inherently dynamic (Berkes, 1999; Gómez-Baggethun & Reyes-García, 2013; Reyes-García, *et al.*, 2016), it has been shown that at least some dimensions of the social-ecological memory of IPLCs are becoming substantially eroded (Ford *et al.,* 2006, 2010; Turvey *et al.,* 2010; Fernández-Llamazares *et al.,* 2015). Rapid social and cultural changes create discontinuity in the transmission of ecological knowledge (Singh *et al.,* 2010; Etiendem *et al.,* 2011; Reyes-García *et al.,* 2010, 2014; Turvey *et al.,* 2010; Shen *et al.,* 2012; Guèze *et al.,* 2015; Luz *et al.,* 2015, 2017), impact the functioning of collective institutions, many of which have supported sustainable resource management and diverse biocultural landscapes for long periods of time (Agrawal, 2001; Oldekop *et al.,* 2013; Fernández-Llamazares *et al.,* 2016, 2018; Sirén, 2017).

Policies focused at revitalizing language and local ecological knowledge also contribute to recognizing and, in some cases, restoring IPLCs' customary institutions for ecosystem management, which have been weakened or eroded (Aikenhead, 2001; McCarter *et al.,* 2014; McCarter & Gavin, 2014; Tang & Gavin, 2016). For example, in contexts where environmental degradation is linked to the loss of cultural values, ILK revitalization efforts have been successfully linked to ecological restoration projects, also providing cultural incentives (Anderson,1996; Long *et al.,* 2003; López-Maldonado & Berkes, 2017; Reyes-García *et al.,* 2018). Some customary education programs have also integrated ILK in school curricula, contributing to strengthen networks of ILK transmission (Kimmerer, 2002; Reyes-García *et al.,* 2010; Ruiz-Mallén *et al.,* 2010; McCarter & Gavin, 2011, 2014; Hamlin, 2013; Abah *et al.,* 2015). Similarly, it has been shown that ILK revitalization efforts are most effective when controlled and managed by the communities involved (Singh *et al.,* 2010; McCarter *et al.,* 2014; Fernández-Llamazares & Cabeza, 2017; Sterling *et al.,* 2017). Moreover, it is important that revitalization efforts consider the gendered nature of knowledge and the crucial role of women in knowledge transmission (Iniesta-Arandia *et al.,* 2015; Díaz-Reviriego *et al.,* 2016).

6.3.2.5 Improving financing for conservation and sustainable development

Financing is a critical determinant of the success or failure of conservation outcomes, as acknowledged in the CBD and SDG which call for increased financing and aid, and Aichi Target 3, which calls for the promotion of positive incentives for the conservation and sustainable use of biodiversity by 2020. These economic tools for biodiversity can include instruments such as biodiversity-relevant taxes, charges and fees; tradable permit schemes; and subsidies that aim to reflect the inherent values of biodiversity in their actual use, which have raised billions in recent years (OECD, 2010b; OECD, 2013). Currently, finance mobilized to promote biodiversity has been estimated at about US$ 52 billion globally (Parker *et al.,* 2012; Miller, 2014), while estimates of the financing necessary to reach international targets range from US$ 76-440 billion per year (CBD, 2012; McCarthy *et al.,* 2012). An estimated 80 percent of biodiversity conservation funding across low and middle income countries is derived from international aid (ODA), with the remaining 20 percent coming from domestic, private and other sources (Hein *et al.,* 2013; Waldron *et al.,* 2013). Other forms of financing besides ODA include direct payments to those who conserve biodiversity through various transfer mechanisms, including PES (see section on *Improving REDD+ and PES,* above), eco-compensation policies, or ecological fiscal transfers (see Supplementary Materials 6.2.4 for details on the latter two). Other financing mechanisms can include tradable permits, in which markets, auctions or other schemes allow those causing biodiversity loss or pollution to compensate their environmental impacts in other locations (see Supplementary Materials 6.2.4).

Though uncertainty exists on overall funding levels (Tittensor *et al.,* 2014), there is widespread agreement that resources are well below needs (James *et al.,* 1999; McCarthy *et al.,* 2012; Waldron *et al.,* 2013) and have failed to meet donor commitments (Miller *et al.,* 2013). Developing country capacity to finance conservation and sustainable use is increasing (Vincent *et al.,* 2014), and initiatives such as the UNDP BIOFIN project (www.biodiversityfinance.net) have assisted countries with identifying options, but ODA is likely to remain the major finance source for now. Existing flows have generally been well-targeted to countries with greater conservation need (Miller *et al.,* 2013), but there is inconclusive evidence about whether these resources have resulted in conservation success. New trust fund and collective fund approaches have been used in recent projects, such as the Amazon Fund to combat deforestation in Brazil (see Supplementary Materials 6.2.4). However, few if any peer-reviewed studies explicitly examine the impact of specific biodiversity financing projects using robust program evaluation methods. Bare *et al.* (2015) find higher rates of forest loss correlated with aid (concluding not that aid caused loss, but that aid was insufficient to halt existing drivers), while Waldron *et al.* (2017) found that conservation funding —much of it is ODA—did reduce biodiversity loss by an average of 29%. There is a paucity of impact evaluations in the conservation sector that examine socio-economic impacts of financing (Börner *et al.,* 2016; Puri *et al.,* 2016). Finally, there is a major gap in assessing the long-term impacts of conservation aid (Miller *et al.,* 2017) (see also Supplementary Materials 6.2.4). All of these gaps suggest a strong need for better systems of tracking and assessing the impacts of different types of financing; in other words, not just more financing is needed, but better understanding of the mechanisms for success.

6.3.3 Integrated Approaches for Sustainable Marine and Coastal Governance

Marine and coastal areas, covering 70% of the Earth's surface, include the High Seas or areas beyond national jurisdiction (ABNJ) which cover nearly half of the Earth's surface (Harris & Whiteway, 2009) and territorial waters from the baseline to national territorial limits. Adding river catchments affecting coastal areas means that much of the Earth's surface is directly connected to marine and coastal biodiversity and ecosystem services. Policy instruments for coastal biodiversity and ecosystem management span the scale of institutions from global and intergovernmental to local communities, and concern many different sectoral, thematic and cultural stakeholder and rights-holder groups. The United Nations Convention on the Law of the Sea (UNCLOS) includes provisions for coastal States to exercise national jurisdictions within 200 nautical miles from the baseline and to meet responsibilities for their Flag vessels on the High Seas.

Most Aichi Biodiversity Targets are relevant to marine and coastal biodiversity, but Targets 6, 7, 10, and 11 are explicit in their coverage of fisheries sustainability and ecosystem-based management (Target 6), sustainable aquaculture (Target 7), and coral reefs subject to anthropogenic pressures and impacted by climate change and ocean acidification (Target 10), and protected areas (Target 11). The ambitious target dates of 2015 (Target 10) and 2020 (Target 6, 7 and 11) have not or will not be met globally by 2020. For the SDG, Goal 14 (life below water) is most explicitly relevant to marine and coastal biodiversity, but most other Goals are also relevant.

At the frontier between land and seas, coastal areas support dense human populations, are undergoing rapid economic development and have been heavily transformed e.g., into cities, ports, tourist facilities and aquatic farms, with profound consequences for biodiversity and ecosystem services such as wildlife habitats and clean water. Downstream of terrestrial material flows, deltas and estuary systems receive nutrient, sediment, sewage, waste and pollution loads from distant regions. On land and sea margins, climate and other hazards are often more severe than inland (United Nations World Ocean Assessment, 2017). Coastal rehabilitation offers some opportunities to partially restore some ecosystem functions after their initial transformation or destruction for human use.

Climate change and pollution caused by land and sea-based carbon emissions and waste disposal are impacting the High Seas and coastal areas. Direct human exploitation of the High Seas is also increasing from fishing, shipping, oil and gas extraction, seabed mining, ocean energy production and aquaculture. Consequently, biodiversity conservation is a key issue in the High Seas (World Ocean Assessment, 2017; Ingels *et al.,* 2017). High Seas biodiversity is experiencing predominantly negative impacts, e.g., Census of Marine Life (Ausabel *et al.,* 2010), including in the abundance and diversity of fauna and in the status of sensitive and unique habitats such as seamounts (Koslow *et al.,* 2017), hydro-thermal vents (LeBris *et al.,* 2017) and deep-sea corals (Cordes *et al.,* 2017).

The use and management of coastal and marine areas are divided among many individual and corporate players whose activities impact the oceans. Unless action is based on sound shared knowledge, the players may fail to act in the interests of conservation (World Ocean Assessment, 2017), e.g., when coastal reclamation projects proceed in ignorance of the potential destruction of ecosystem services. In addition, the rights of different players may be unequal. For example, IPLCs are often long-established inhabitants and users of the coastal environment, but their access and ownership often are not secured against larger economic activities.

Following the Rio 1992 Earth Summit, conservation groups, governments and researchers increased attention to fisheries and other coastal industries impacting biodiversity and ecosystem services (Spalding *et al.,* 2013; Garcia *et al.,* 2014). Despite the raised awareness, action has been slow. For example, despite the ocean's importance in climate, oceans will be a major priority only in the 6th assessment cycle of the IPCC, due for completion in 2022. After ten years of discussion, in 2017, the UN General Assembly resolved (Resolution 72/249) to convene a conference to develop an international legally binding instrument under UNCLOS in order to address the conservation and sustainable use of marine biodiversity of ABNJ and marine genetic resources benefits sharing.

Governance of marine conservation still faces major challenges including a lack of proper international and regional legal framework for emerging challenges such as the impact of climate change on marine biodiversity. Another major problem is non-implementation of existing legal instruments in international, regional and national levels. Cases that illustrate these problems have been exposed in the IPBES regional assessments. For instance, the regional assessment for Europe and Central Asia highlights that, although the Regional Seas Conventions are playing an important role in joint management of marine areas, the performance is uneven and application not consistent with modern conservation principles and capacity of the region (IPBES, 2018a). The regional assessment for Asia and the Pacific highlights the absence of regional seas conventions or other binding legal instruments for promoting regional joint governance of marine areas (chapter 6, pp. 520-525).

This section presents both short and long-term policy options contributing to integrated approaches to marine and coastal governance. This ranges from identifying governance gaps, including in legal frameworks, and conditions that may facilitate the implementation of available policies in response to immediate needs **(Table 6.4)**.

Table 6 4 **Options for integrated approaches for marine and coastal governance.**

Short-term options	Long-term options (in the context of transformative change)	Key obstacles, potential risks, spillover, unintended consequences, trade-offs	Major decision maker(s)	Main level(s) of governance	Main targeted indirect driver(s)
Global marine and coastal					
Implementing global marine environment agreements for shipping		• Industry resistance due to competitive pressures, lack of awareness and lack of commitment • Practical weaknesses undermining the agreement effectiveness, e.g., flag state enforcement of MARPOL • More enterprises operating outside legal regimes	• International (e.g., IMO) • Regional (inter-) governmental organisations, • national, sub-national and local governments, including government linked authorities, e.g., port management • Shipping and logistics industry	International, regional, national, local	Economic, institutions
	Mainstreaming climate change adaptation and mitigation into marine and coastal governance regimes	• Lack of scientific knowledge to design practical measures • Lack of funding, industry and government support • Risk of resource declines, loss of human living space, food Lack of governance mechanisms to coordinate responses on necessary scales	• International inter-governmental agencies, • International and regional funding bodies • Regional and national sectoral agencies • Conservation-directed public-private financiers • Science and educational agencies • Donor agencies • IPLCs	International, regional, national, local	Economic, institutions, governance, technological

Short-term options	Long-term options (in the context of transformative change)	Key obstacles, potential risks, spillover, unintended consequences, trade-offs	Major decision maker(s)	Main level(s) of governance	Main targeted indirect driver(s)
	Mobilising conservation funding for the oceans	• Lack of private sector funding and very high reliance on public funds • Lack of investment assurance • Need for innovative financing mechanisms	• Maritime industries • International and national, governments	International, national	Economic, institutions, governance
International waters: High Seas (ABNJ) and regional waters					
Improving shared governance		• Maritime territory disputes • Ocean grabbing and failure to fully incorporate human dimension in conservation and resource governance • Differences in legal regimes of adjacent regions	International, regional, national and local governments	International, regional, national, local	Economic, institutions, governance, regional conflicts
Mainstreaming nature and its contributions to people		• Low national priority to biodiversity conservation • Current sectoral conservation efforts often need scaling up • Enforcement costs high, but electronic methods offer new options • Conservation and sectoral agency efforts need greater coherence	• International, regional and national governments, management agencies, NGOs, industry, IPLCs, Consumers	International, regional, national	Economic, institutions, technological, governance
	High Seas convention	• No legally binding international law for comprehensive protection of biodiversity	• International and national governments, • Non-governmental agencies, • Private sector	International, national	Economic, institutions, governance
Coastal waters					
Promote integrated management		• Long time frame and planning often stronger than implementation; • High transactions costs or fixed trade-offs can make system slow to respond to changing pressures or needs of coastal communities	• National central, sectoral agencies, NGOs, local and sub- national agencies, private sector specific to context, IPLCs	National, local	Economic, institutions, technological, governance
Mainstreaming nature conservation in sectoral management, with an emphasis on fisheries		• Widespread overfishing, pollution and habitat destruction, subsidies, IUU, market incentives • Weak progress in implementing existing fisheries governance framework • Solutions are context specific	• National governments, private sector management options, regional and international organisations, NGOs, industries and fishers organisations	International, regional, national	Economic, patterns of production, supply and consumption, governance, technological
Scaling up from sub-national project pilots		• Local conservation needs often precede national policies, but scaling up local solutions enables cooperation across local jurisdictions • Locally developed solutions may not be fully transferrable to other local situations	• National and local governments, IPLCs, Citizen groups	National, local	Economic, institutions, governance

Short-term options	Long-term options (in the context of transformative change)	Key obstacles, potential risks, spillover, unintended consequences, trade-offs	Major decision maker(s)	Main level(s) of governance	Main targeted indirect driver(s)
Building ecological functionality into coastal infrastructure		• Ineffective planning and approval processes for development • Insufficient financial and human resources for monitoring	• National and local governments, private sector	National, local	Economic, institutions, governance
Engaging stakeholders to achieve common ecological and social good outcomes		• Stakeholders not working together on solutions	• International and national NGOs, private sector governments, scientists and educationists, IPLCs	International, national, local	Economic, institutions, governance, cultural

6.3.3.1 Global Marine and Coastal

Overarching global policies and processes, including and beyond climate change-related agreements have had major impacts on action to protect marine and coastal biodiversity and ecosystem services (chapter 2.1 and 3). In the present section, we focus on key global agreements that need to be integrated into policy for marine and coastal biodiversity and ecosystem services.

6.3.3.1.1 Implementing global marine environment agreements for shipping

History shows that global agreements regarding shipping are challenging to negotiate, and, once agreed and ratified, challenging to implement, and in motivating government, industry and community stakeholders to act. The existing conventions and protocols on vessel-sourced pollution, including exotic and potentially invasive species from ships' hull fouling and ballast water, are important examples as shipping grows (World Ocean Assessment 2017, chapter 17).

Several international maritime agreements on the environment pre-dated UNCLOS, notably the International Maritime Organization (IMO) International Convention for the Prevention of Pollution from Ships, 1973 – MARPOL (Karim, 2015). UNCLOS was critical, however, as it introduced the regulatory framework of duties and jurisdiction of states addressing the main sources of ocean pollution, the success of which heavily depends on detailed regulations and their enforcement by international, regional and national institutions. Despite wide convergence of shipping issues and participation of most of the countries as well as the considerable success of IMO Conventions, worldwide uniform enforcement, monitoring and control still need development (Karim, 2015). Enforcement, monitoring and control relied greatly on flag state enforcement (Mattson, 2006) but in addition, port-state enforcement is being applied in some maritime agreements, such as the Food and Agriculture Organization Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (2009). This combined with new satellite and information technologies are being applied in efforts to track compliance, but enforcement is still weak (Petrossian, 2015). Enforcement and implementation are lacking both within and beyond national jurisdiction (Karim, 2015, 2018), but regional cooperative arrangements may improve regulatory capacity and should be further strengthened. In addition, a coordinated and widespread initiative for capacity building to strengthen understanding of and capacity for flag state responsibility in the global regulatory apparatus is needed to combat pollution in the areas beyond national jurisdiction (World Ocean Assessment, 2017).

6.3.3.1.2 Mainstreaming climate change adaptation and mitigation into marine and coastal governance regimes

Coordinated measures are needed to combat climate-related stressors on marine biodiversity, e.g., ocean acidification, ocean warming and deoxygenation (Bijma *et al.,* 2013; Pörtner, 2014; Levin *et al.,* 2018), as these stressors have sectoral effects, such as on stable fisheries agreements (Brandt & Kronbak, 2010; Galaz *et al.,* 2012). In fact, the Paris Agreement is now the first climate agreement to explicitly consider the ocean. International and regional legal instruments and mechanisms for climate change, oceans, fisheries and the environment are relevant for these challenges, but they remain inadequate (Galland *et al.,* 2012; Herr *et al.,* 2014; IPCC, 2017). At the least, sectoral and general ocean governance will have to mainstream major climate issues in governance regimes at international, regional and national levels. This mainstreaming will help sectoral management adapt and mitigate emissions. If linked to climate actions, this may also help reduce some of the knowledge gaps on climate and the ocean, and gaps between scientific and government attention to climate change (Magnan *et al.,* 2016; Gallo *et al.,* 2017). Achieving policy coherence over such complex issues also requires significant new knowledge on the oceans and climate which can feed back into climate science. In the case of proposed climate solutions such as geoengineering to capture carbon from the atmosphere, the IPCC warns that the impacts on marine ecosystems "remain unresolved and are not, therefore, ready for near-term application" (http://www.ipcc.ch/ipccreports/tar/wg3/index.php?idp=25).

Many impacts of global changes are highly unbalanced, because telecouplings affect people who have not caused the problems. Sea level rise is eroding the living space of many marginal coastal people in developing countries, e.g., on low-lying Pacific islands and coastal mangroves in Asia. Funds set up to address these transfer issues, e.g., the Green Climate Fund and other multilateral instruments will not have their intended effects unless greater priority is given to developing countries (Friends of the Earth and Institute for Policy Studies, 2017), and these funds need to specialize and cooperate effectively to provide coherent support (Amerasinghe *et al.,* 2017).

6.3.3.1.3 Mobilising conservation funding for the oceans

According to some estimates, the oceans provide trillions of USD annually in goods and services to society (Costanza *et al.,* 1997). Policies and incentives towards the sustainable use of the oceans – from controlling overfishing and pollution to promoting new technologies for energy and carbon sequestration to incentives for sustainable tourism – have economic and social impact across sectors of society and regions, benefiting private and public economies, and local communities. However, innovative solutions are needed for improving financing for conservation action for the ocean. Some estimates suggest that that market-based mechanisms could, for example, deliver up to 50% of the finance for coral reefs (Parker *et al.,* 2012), including for instance cap-and-trade programs such as the Ocean Appreciation Program (Ocean Recovery Alliance, 2016), green bonds (Thiele, 2015a), and blue carbon sequestration to benefit biodiversity (Maldonado & Barrera, 2014; Murray *et al.,* 2011; Thiele & Gerber, 2017). On the High Seas, the financial mechanisms to support conservation are not well established and new institutional financial structures, including financial solutions that allow for private funds to be invested in conservation, such as from international markets, are increasingly recognized as essential (Madsbjerg, 2016).

The majority of current biodiversity funding is from public finance (e.g., GEF) (Huwyler *et al.*, 2014) and is affected by the short-term time horizons of political agendas and public opinions. Following models used in climate (Buchner *et al.,* 2015) and development finance (Gutmann & Davidson, 2007), growing attention is given to the potential use of market-based mechanisms used in terrestrial systems for the High Seas, such as payments for ecosystem services and biodiversity offsets (Gjertsen *et al.,* 2014).

Clean, renewable ocean-derived energy has the potential to reduce carbon emissions and meet 10 percent of EU demand by 2050 (Ocean Energy Europe, 2015). Technologies of this magnitude, however, are impeded by high initial investments and risks. These barriers may be overcome through public-private collaboration and require careful planning and environmental impact assessment (Economist Intelligence Unit 2015). There is potential for increased research and infrastructure support for wave and tidal energy technology, which have been slow in terms of technological advancements (REN21, 2018; Bruckner *et al.,* 2014).

A portion of the profits from ocean-based goods and services could be directed into conservation research, monitoring, and enforcement. For example, ocean tourism, managed with respect for, with and by local communities, can yield successful results if earning from tourism are funneled into supporting sustainable management (Cisneros-Montemayor *et al.,* 2013; Hess, 2015); and appropriate incentives in fishing could help change current practices such as derelict gear that threaten habitats and natural capital stocks (Grafton *et al.,* 2006; Grafton *et al.,* 2008).

Global cooperation is needed to develop innovative mechanisms to conserve the ocean, just as global collaboration is needed to address air quality and atmospheric emissions. Ocean conservation projects may be funded by a proposed Ocean Bank for Sustainability and Development and trust funds. The Ocean Bank concept has been supported by several NGOs that argue current development banks and structures are not sufficient for the largest ecosystem (WWF, 2015). Proponents envision that this new institution arrangement could be funded by states and private investors, providing knowledge, project development, training, and financing (Cicin *et al.,* 2016). Trust funds can offer long-term financial assistance and have already been applied to marine conservation management (MAR Fund, 2014; MRAG, 2016), e.g., a fund for a protected area in Kiribati compensates the government for license profits forgone (MRAG, 2016).

In the last 20 years, conservation organisations – international, national and local – e.g., IUCN, WWF, CI, TNC, WCS and their local chapters – have developed major coastal conservation programs, supported by funding from (mainly) US based philanthropic foundations (Packard, Walton, Pew, etc.) and often giving particular attention to charismatic ecosystems, e.g., coral reefs, and mega-fauna, e.g., whale shark, cetaceans and other marine mammals, and penguins. However, as the foundations turn more to Blue Economy issues such as fishing and food security, their future efforts may not be so focused on biodiversity conservation, calling attention to the importance of diversifying funding mechanisms supporting marine and ocean conservation and sustainable use.

6.3.3.2 International waters: High Seas (ABNJ) and regional waters

Significant areas of the ocean are outside settled national jurisdictions, although certain activities may be under the controls of regional bodies or of global agreements. Some disputes over precise jurisdictions remain. A few countries, including the USA, have not signed the United Nations Convention on the Law of the Sea (UNCLOS), but largely abide by its provisions. The High Seas sustain global-scale ecosystem functions and provide essential benefits to humans (Rogers *et al.,* 2014) but are subject to three increasing trends (World Ocean Assessment, 2017). First, human needs are increasingly met from the ocean, some directly, e.g., food from fisheries, aquaculture and ranching (Ferreria *et al.,* 2017; APEC, 2016), and some indirectly, e.g., greater shipping of commodities in an increasingly globalized world (Simcock & Tamara, 2017; Simcock, 2017). Second, direct drivers affecting the High Seas are expected to increase, including fishing, aquaculture, mining, energy and defence activities, sound pollution from transportation, and chemical and biological pollution from increased use of the sea and coastal living. Third, as efforts to increase the sustainability of ocean uses within national jurisdiction increase (FAO, 2016; CBD, 2017), some of the effort is moving offshore (Merrie *et al.,* 2014; Gjerde *et al.,* 2013). These three trends have major impacts on nature and its contributions to people, including the challenge of managing rapidly emerging industries such as mining, undersea communications and energy. Improving shared governance, mainstreaming nature, and a new High Seas convention are proposed as options.

6.3.3.2.1 Improving shared governance

Supporting and expanding existing conservation cooperation mechanisms represent a promising short-term option for protecting High Seas biodiversity. Some of these institutions are expanding their initiatives into areas beyond national jurisdiction, e.g., through fisheries observer programs, anti-IUU (illegal, unreported and unregulated) fishing measures. Regional organisations, particularly, the Regional Seas Programmes, Regional Fisheries Management Bodies and their conventions, and GEF Large Marine Ecosystems (LME) programmes can also play an important role in combating land-based marine pollution.

A common first step in establishing international coastal cooperation is a transboundary programme of technical cooperation, such as the Regional Seas Programmes and Conventions and the GEF initiated LME projects. Many of these programmes have helped create effective environment agreements among countries.

Territorial disputes may impede conservation, to the extent that in contentious areas, multilateral cooperation has been limited to technical cooperation among a subset of countries rather than active management (Williams, 2013). Where maritime territory disputes remain, countries are urged to settle these through the UNCLOS legal routes. UNCLOS offers four options for dispute settlement and by finding the means that best suits, states have settled many disputes. However, instances where some of the large powers have opted not to resort to UNCLOS dispute settlement system may jeopardize the effectiveness of the forum (Klein, 2014; Gates, 2017).

“Ocean grabbing” is a term used to describe an emerging concern over the dispossession or appropriation of ocean space or resources from prior users, rights holders or inhabitants resulting from governance processes with power asymmetries among participants. More broadly, the issue of accumulation by dispossession is both an issue that can impede conservation and be used by conservation interests to obtain a foothold over community lands (Harvey, 2003; Hall, 2013; Benjaminsen & Bryceson, 2012). If the needs of local communities and ecosystems are not fully taken into account, allocation of access rights to ocean space or resources may undermine human security and impair biodiversity components. Conservation allocations such as marine protected areas, and rights-based approaches such as individual fisheries quotas may be conducted in ways that do not undermine human security and ecological functions (Bennett *et al.,* 2015).

Thinning and disappearing sea ice, melting permafrost, and circumpolar climate change, however locally and regionally varied, are commonly identified as playing their part in rapidly unsettling the geographies of Arctic governance (Overland & Wang, 2013; Smith & Stephenson, 2013; Hussey *et al.,* 2016; Stephenson, 2018). Strategies are being sought that will promote renewed international cooperation and reduce the risks of discord in the Arctic, as the region undergoes new jurisdictional conflicts and increasingly severe clashes over the extraction of natural resources in a region that is critical to the prevision of globally important NCPs (Berkman & Young, 2009; Young, 2010; Keil, 2015; Hussey *et al.,* 2016; Harris *et al.,* 2018).

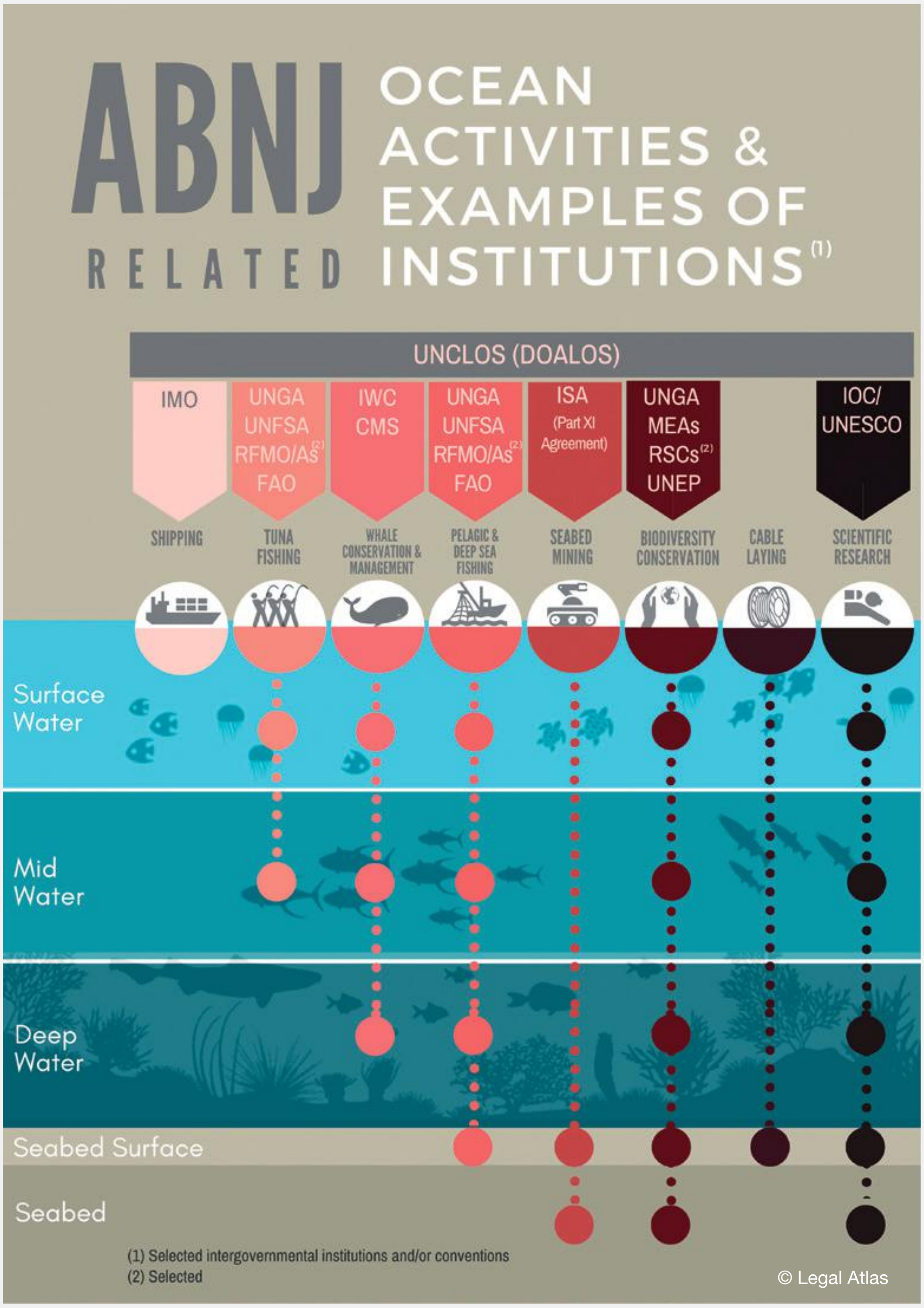

Figure 6 3 **Multiple ocean uses and examples of institutions related to areas beyond national jurisdiction illustrating the different ocean depths relevant to the activities and institutions.**

Source: UNEP-WCMC (2017).

Several organizations have advocated for the negotiation of a harder law regime for the Arctic (Kankaanpää & Young, 2012), including firmer institutional, financial and regulatory foundations for the Arctic Council (Berkman & Young, 2006) and improved transboundary conservation planning (Greenpeace, 2014; Hussey *et al.,* 2016; Edwards & Evans, 2017; Harris *et al.,* 2018).

6.3.3.2.2 Mainstreaming nature and its contributions to people

Recognising the rising pressures on biodiversity on the High Seas, most sectoral regulatory agencies are recognizing the need to mainstream biodiversity conservation into their approaches to policy and management (CBD, 2016). Responding to growing public pressure from NGOs and international agencies, measures are being introduced. For instance, Regional Fisheries Management Organisations (RFMOs) are implementing UNGA Resolution 61/105 to protect deep sea Vulnerable Marine Ecosystems (VMEs) from bottom trawling (Rice *et al.,* 2017). Similarly, sectoral agencies such as the International Seabed Authority for deep-sea mining (Anton, 2011) and International Maritime Organisation for shipping are adopting, or urged to, additional policies and measures to manage and mitigate the pressures of these sectors on High Seas biodiversity and their habitats.

The effectiveness of conservation policies for the High Seas depend crucially on how well they are implemented, a challenge that sectoral regulatory agencies have been grappling with for decades. In some areas, there is a need for substantive scaling up resources and prioritizing areas of rising pressure, e.g., for tuna fisheries (Juan-Jorda *et al.,* 2017). A major obstacle is the lack of priority that countries give to international arrangements for nature conservation. The latter highlight the role of regional management bodies and their secretariats in mobilizing action, and that of NGOs that advocate action through campaigns engaging public attention and presenting submissions to management bodies.

The experience of RFMOs in protecting VMEs from deep sea fishing shows that a strong science foundation is crucial as the knowledge basis (MacDonald *et al.,* 2016), in addition to guidance on suitable conservation management measures (FAO, 2009). As little of the seabed is mapped, however, the knowledge base is generally poor. Protection is still feasible using responsive mechanisms based on existing knowledge, e.g., real-time move-on (cease-fishing) rules triggered when the presence of a VME is identified through bycatch indicator taxa; and great progress on identifying VMEs and Ecologically and Biologically Significant Marine Areas, even with incomplete information (Dunn *et al.,* 2014).

For RFMOs and other sectoral agencies, member States need to provide costly surveillance and enforcement (Rice *et al.,* 2014). These functions present a greater challenge on the High Seas than within national jurisdictions, but additional policy interventions have enhanced the effectiveness of existing policies, e.g., the FAO Port State Measures Agreement (2009, in force 2016) increased the effectiveness of other measures to deter IUU fishing (FAO, 2017). Sectoral management agencies, including fisheries, and NGOs such as Global Fishing Watch, are now testing new technologies such as satellite monitoring of electronic fisheries operations, onboard CCTV monitoring of catch and bycatch, and real-time data entry (Hosken *et al.,* 2016). These technologies can lead to better monitoring, control and surveillance.

Greater efforts are needed to achieve coherence between the efforts of sectoral management agencies and the efforts of biodiversity conservation agencies, including those led by intergovernmental organizations such as the CBD, e.g., program for identifying Ecologically or Biologically Significant Areas (EBSAs – Johnson *et al.,* 2018), and by NGOs, e.g., Birdlife International. In fisheries, poor coherence leads to low returns on conservation and management investments (Garcia *et al.,* 2014a). The obstacles to improving coherence are high because it requires governance processes with convening power to bring the agencies together, the duty to cooperate both in selecting policies and measures that work synergistically and implementation strategies that encourage cooperation (Garcia at al., 2014b).

6.3.3.2.3 Pathways to protect nature in the High Seas

The need for coherence poses the greatest challenge, and greatest opportunity, for changing the trends of loss in High Seas biodiversity. The limitations of UNCLOS to deal effectively with nature conservation in the High Seas biodiversity was recognized over a decade ago. Open Ended Working Groups of the UNGA (http://www.un.org/depts/los/biodiversityworkinggroup/biodiversityworkinggroup.htm) prioritized three themes: the ability to apply spatial management tools, including High Seas Marine Protected Areas (MPA) binding on all marine industry sectors; marine spatial planning across sectoral agencies; access and benefits sharing to marine genetic resources; environment impact assessment, technology transfer and capacity building.

UNGA has initiated in 2017 an intergovernmental conference on an international legally binding instrument under UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (General Assembly Resolution 72/249); with expected conclusion in 2020. These negotiations will be a major factor in the future trajectories of High Seas biodiversity. An eventual future instrument is likely to include provisions for area-based management including MPA, environmental impact assessment and marine genetic resources. National government are encouraged to support the timely agreement of an effective instrument for marine protection and then implement the provisions with regard to key sectors, e.g., fishing, seabed mining, coastal oil and gas, geoengineering and waste disposal.

6.3.3.3 Coastal Waters

National governments play a major role in determining the balance of coastal protection and resource use, and global codes and conventions can help promote national action, e.g., SDG 14 (life below water). Governments face the challenges of harmonising and coordinating responsible agencies and interests, setting national policies and priorities, coordinating and integrating planning, resourcing, implementing, monitoring and reporting. Locally led initiatives can also feed up into national policies (see 6.3.3.3.3).

6.3.3.3.1 Promoting integrated management

Since the 1980s integrated coastal environment management concepts have been a focus of academic attention (Merrie & Olsson, 2014). Conservation, international and national organisations also have promoted, developed and piloted several related forms of integrated marine and coastal management, especially Integrated Coastal Management (ICM) and Sustainable Development in Coastal Areas (ICM/SDCA – http://www.pemsea.org/our-work/integrated-coastal-management/SDCA-framework), MPA, Marine Spatial Planning (MSP) (Ehler & Douvere, 2009) and Ecosystem Based Management (EBM) (Agardy *et al.,* 2011). MSP and MPA illustrate the challenges.

MPA have been applied most commonly to fisheries and special area conservation. Their effectiveness depends on the economic conditions, governance and institutional contexts in which in which they are applied (Agardy *et al.,* 2011; Ban *et al.,* 2013; IPBES, 2018c), their location (Mouillot *et al.,* 2015), and local livelihood activities that are displaced by the MPA must be addressed (Cudney-Bueno *et al.,* 2009; Bennett & Dearden, 2014; IPBES, 2018d).

Conversely, when MPA management incorporates biophysical, economic, and social characteristics of the system, more sustainable fishing practices may result (Cinti *et al.,* 2010; Sciberras *et al.,* 2015; Gill *et al.,* 2017).

MPA and systems of interconnected MPA offer conservation management options for both the short and long term, for governments, private, NGO, and IPLC actors. The social and economic benefits of MPA can improve community well-being via increased income from fisheries or tourism (McCook *et al.,* 2010), and IPLCs can engage in stakeholder processes so that MPA benefit both people and nature (Bennett & Deardan, 2014). The private sector can contribute innovative financing for implementing and enforcing MPA (Theile & Gerber, 2017). Rights-based approaches to MPA management and ocean governance offer a promising option to strengthen MPA and MPA Networks implementation (Bender, 2018). NGOs have an important role to play in implementing MPA, through assisting community engagement and capacity building, monitoring and evaluation, and developing and implementing economic incentives to support MPA (Mascia *et al.,* 2009).

Marine spatial planning (MSP) is a comprehensive "public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objective *that are usually specified through a political process."* (IOC-UNESCO Marine Spatial Planning Programme – http://msp.ioc-unesco.org/). It evolved together with MPA developments (Katsanevakis *et al.,* 2011), bringing together multiple users of the ocean – energy, industry, government, conservation and recreation. Not an end in itself, intent of MSP is a coordinated and sustainable approach to ocean use. Policy-relevant guidebooks have been developed to support implementation (e.g., Ehler & Douve, 2009). Despite good pilot cases and some success, a 2012 review concluded that: "Comprehensive MSP initiatives are relatively new and thus largely untested. In those that are underway, there appears to be greater emphasis on planning than on post-plan implementation" (Secretariat for the CBD and GEF, 2012, p.32). Furthermore, the requirements of cross-sectoral decision-making can be seen by line ministries as onerous and undesirable (Secretariat for the CBD and GEF 2012), although this is clearly very important in implementing the mainstreaming requirements of the CBD. A further challenge is that the adaptable nature of MSP must continually maintain a balance of ecosystem conservation and economic and social aims (Merrie & Olsson, 2014), making frequent updates and adaptive responses necessary. National capacity to implement integrated environmental stewardship can be affected also by the relative powers of the ministries. In some governments, environment ministries are newer and weaker compared to economic and central ministries (Jordan *et al.,* 2010).

Overall, the obstacles to implementation, longer time frame for success, complexity of the integrated solutions, and need to be responsive to changing externalities (e.g., climate change, new trade agreements, changing markets for traditional products, etc.) all mandate that governance arrangements focus also on shorter term responsive action, including sectoral in cases, to address the most immediate problems in a step by step approach. Nevertheless, sectoral or local actions need to be nested with higher level institutions adjudicating on cross-sectoral trade-offs resulting from specific actions, such as those competing for coastal space: ports, urban development, fisheries, tourism, and conservation.

Integrated management at the national and local levels: National governments, pivotal to integrating management across scales and to negotiate international and regional agreements. Typically, an international agreement is the catalyst for national action, however avoiding piecemeal solutions is difficult since local and national levels actors are continuously responding to accelerate social and environmental changes. On the other hand, localized solutions can be effective. For instance, while a global instrument against plastic pollution will take time, national and sub-national actions are contributing to address the problem (Niaounakis 2017). National and state governments, for instance, can impose restrictions on the sale and use of single-use plastic bags, for instance as did Chile in 2017 in restricting such items particularly in coastal villages and towns.

Decentralizing policies to sub-national and local governance have a direct impact on the type of coastal and marine management. In the last three decades, coastal and marine management has been affected by the opportunities and challenges caused by national re-organisations associated with the devolution and decentralisation of government powers to state, province or local government and community levels, requiring rapid capacity building at sub-national levels. In Southeast Asia (e.g., Indonesia, Philippines and Vietnam) devolution models were embraced with varying results. Indonesia has received major World Bank development and conservation support for community and local government-based empowerment, and the local outcomes covered the spectrum from responsible leadership, to elite capture, patronage networks, and outright corruption (Warren & Visser, 2016). Another example of diverse outcomes of local level management is the coastal cities in the Great Buenos Aires conurbation (Argentina), comprising ten different jurisdictions at national, provincial and municipal government level. Responding to local politics and globalization pressures on competitive industries, decades of decentralization or federation efforts were resolved essentially in favour of decentralisation rather than metropolitan integration (Dadon & Oldani, 2017).

Successful short and medium-term sub-national interventions can include small scale actions and projects at sectoral or cross-sectoral level, as for this scale, sectoral boundaries may not be so rigidly delineated. Technical projects, research institutes (as entry points for diagnosis, finding solutions, monitoring status) and community, including youth, engagement, are critical elements to the success of grassroots conservation.

Indigenous Peoples and Local Communities are central to sub-national marine conservation action but vary significantly in terms of their capacities and needs to manage marine resources under different types of pressures. Across the world, the position and contribution of IPLCs to coastal management vary significantly from areas where communities retain full control to various types of mixed arrangements, to complete deprivation of rights. Evidence demonstrates that local customary institutions can be more effective than formal external ones in promoting management. In Indonesia, continuous traditional marine management such as *sasi laut* and *pangalima laut* were more potent and likely to be obeyed than more modern proclamations, e.g., of Marine Protected Areas (Harkes & Novaczek, 2002; Wiadnya *et al.,* 2011). In Sumatra with well-conceived external support, even cases of corrupt devolved authority could be turned around into local community advantage (Warren & Visser, 2016).

6.3.3.3.2 Mainstreaming nature conservation in sectoral management, with an emphasis on fisheries

National resource managers of coastal waters, private sector enterprises, citizens and consumers can all play a role to help prevent environmental damage, including by protecting vulnerable areas, changing damaging manufacturing practices, sensitive land development, waste disposal and consumption patterns. Collectively, these mainstreaming approaches are now being referred to as ecosystem-based approaches to management within specific sectors. Sectoral activities and policy often determine the conservation approaches but focus on components of nature most closely linked to their sectoral activities. For example, fisheries experts have been early to diagnose environmental problems such as fish stock overexploitation and bycatch, but less likely to focus on a seabird colony finding insufficient food because of a fishery harvest. Effective governance is needed to ensure sectors do not prioritize resource uses to a level that risks unsustainable practices.

In addition to risk of overharvesting, the IPBES regional assessments for Africa, the Americas, Asia and Pacific, Europe and Central Asia found that fisheries conservation is threatened also by other external threats, including many types of pollution, habitat destruction for industries and human living space, invasive alien species from sources including ballast water introductions, nutrient driven hypoxia, jelly-fish blooms, and climate change. These problems call for the joint effort of governance institutions from local, to national, and regional, and even global.

Managing the impacts of fishing and fish supply chains to conserve the target stocks and the environment has become a recognized environment priority, e.g., SDG target 14.4 and Aichi target 6. One-third of marine fish stocks (including invertebrates) are fished at biologically unsustainable levels, 60% at sustainable levels, and 7% underfished (FAO, 2018a). However, many marine fish stocks are of unknown status, suggesting that estimates about sustainable fisheries management may be over-optimistic (FAO, 2018a). Positively, there is evidence that stock rebuilding is occurring in countries including USA, Australia, Namibia, Canada, and the European Union (FAO, 2018a). However, evidence on ending overfishing and rebuilding depleted stocks suggests that the successful recovery of depleted marine resources depends possibly more on management of infrastructure and socio-economic contexts than on having accurate stock assessments alone, especially if management measures that are suited to data-poor fish stocks are used (e.g. IPBES, 2018c; Brodziak *et al.,* 2008; Rosenberg *et al.,* 2006; Caddy & Agnew, 2004; Garcia *et al.,* 2018).

Despite evidence for the need to address overexploitation from fishing, many countries and RFMOs have not fully implemented the extensive international legal framework, including both hard and soft law instrument, referred to as the Code of Conduct for Responsible Fisheries and its instruments (FAO, 2012). The World Ocean Assessment (United Nations, 2017) proposed the following options: ending overfishing and rebuilding depleted stocks; eliminating IUU fishing; reducing the broader ecosystem impacts of fishing including habitat modification and effects on the food web; reducing the adverse impacts of pollution; and reducing the adverse impacts of perverse subsidies.

A major challenge is that the options are highly context specific and need to be purpose built, albeit lessons can be learned from practice elsewhere and locally specific solutions involve opportunities for co-management. Developed countries may use complex, data rich ecological-economic models (Nielsen *et al.,* 2018), but the models, management institutions and methods, e.g., catch shares, individual transferable quotas (ITQs), may not suit developing country and small-scale fisheries. Specific cultural and ecological contexts are important for successful community-based fisheries management, making any model hard to upscale (Poepoe *et al.,* 2007), although local leaders, social capital and incentives were found to be important (Gutiérrez *et al.,* 2011).

Communities making a living from small-scale fishing and coastal resources have often been ignored in national and international policy, despite their strong dependency on the resources (García-Quijano *et al.,* 2015). Furthermore, assessments, including the present one, generally neglect to consider women's role in this sector and thereby ignore major unrecorded fish catches (Gopal *et al.,* 2017). As well as women, policies need to consider the rights and concerns of Indigenous Peoples with respect to livelihoods, equity and rights, participating and contributing knowledge to fisheries and coastal ecosystem management (Capistrano & Charles, 2012; Fisher *et al.,* 2015). The 2015 Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF-VG) were developed to overcome the neglect of local communities, indigenous and non-indigenous. Countries are encouraged to implement the SSF-VG, which incorporates comprehensive environmental as well as human rights and equity principles.

"Balanced harvest" (Garcia *et al.,* 2016) has been debated as a possible approach to increase food from the sea while maintaining sustainable fisheries but evidence on its effectiveness is lacking as it has not yet been implemented.

To address sustainability through eliminating IUU fishing, countries and Regional Fishery Bodies should not only exercise effective fisheries management, but also implement strong surveillance capacities, e.g., Petrossian, 2015, (see 6.3.3.2.1 and 6.3.3.1.1) and adequately invest in research and technical capacity, for instance improving recognition of illegal landing species and sizes (e.g., Romeo *et al.,* 2014).

Customized options to reduce and eliminate bycatch and discards are essential to minimize ecosystem impacts of fishing (Hall *et al.,* 2017; Gladics *et al.,* 2017; Gilman *et al.,* 2016, Little *et al.,* 2015; Broadhurst *et al.,* 2012). National measures to reduce the direct impacts of fishing on marine mammals, sea turtles and seabirds have proven successful (Grafton *et al.,* 2010). In fisheries for migratory species and in remote ocean areas like those in the Southern Ocean, international inter-organizational collaboration is needed (Osterblom & Bodin, 2012). In addition to managing bycatch and discards, reducing the broader ecosystem impacts of fishing depends on establishing new and implementing current MPA, and restoring critically endangered ecosystems (e.g., Kennelly & Broadhurst, 2002; Fourzai *et al.,* 2012). Adoption of the ecosystem approach to fisheries across countries has, according to FAO, been slow but has consistently moved forward (FAO, 2018b).

Fishery subsidy reforms, which includes elimination of harmful subsidies, decoupling subsidies from fishing effort, re-orienting subsidies to management and technological improvements, conditioning subsidies on fishery performance, and substitution of ongoing subsides for buyback schemes (Cisneros-Montemayor, 2016; Tipping, 2016) are innovative attempts to redress current failures in the interest of resource protection and sustainability.

Seafood certification and ecolabelling are economic instruments designed to change consumer seafood demand for well-defined target species or fisheries whose sustainability is under threat, direct them to better environmental choices, create market access, and provide incentives to improve fishing practices through price premiums to producers (FAO 2018b). The uptake of these schemes has been much greater in developed countries and is considered to have had the most important non-State positive impact on fisheries sustainability, but more efforts are needed to increase its uptake and the lower barriers to entry for developing country and small-scale fisheries (Gutierriz *et al.,* 2016; FAO, 2018b). In view of the diversity of ecolabelling and certification schemes have developed, for which FAO has established a Global Benchmark Tool. To date, only three fisheries and one aquaculture scheme have been benchmarked. Several schemes are now addressing social standards but as yet these lack agreed performance norms (FAO, 2018b). As precursors to certification, fisheries improvement programs (FIPs) are important stepping stones towards sustainability (https://fisheryprogress.org/).

Certification and ecolabelling have had a major positive impact on improving fisheries sustainability and, for developed counties, may be the most important recent non-government fisheries management initiative. Evidence shows that support of governments and other fisheries actors are essential for fisheries certification (Gutierrez *et al.,* 2016). Controversy over certificate standards and questions over accountability for the certification machinery and decisions have arisen (Miller & Bush, 2015; Gulbrandson & Auld, 2016). In addition, certification has had only modest success so far in including developing countries and small-scale fishers and producers. A further challenge is that only some consumers are yet willing to pay more for certified seafood (FAO, 2018b).

6.3.3.3.3 Scaling up from sub-national project pilots

National agencies, including government science and management agencies, play key roles identifying, diagnosing, researching and developing technical projects and pilots on marine biodiversity conservation, often following specific sub-national cases, such as Australian efforts to sustainably manage competing uses of the Great Barrier Reef Marine Park (Merrie & Olsson (2014).

Scaling up is the challenge for sub-national initiatives. In Asia, the PEMSEA partnership has demonstrated the feasibility of building on small scale local success. For example, in Batangas, Philippines, efforts spread from five local authorities to 34, covering the watershed and coastal areas of the whole province (http://www.pemsea.org/our-work/integrated-coastal-management/ICM-sites). By 2021, ICM is expected to reach 25% of the East Asia region's coastline using the PEMSEA model that has performed well in East Asia, as national governments collaborate towards a regional strategy. The work starts at the local government level, rather than relying on national policy to initiate action. Like other integrated approached, ICM relies on networks of experts reaching out to interested local actors, having also attracted attention from international donors.

Successful examples of local governance, albeit with external support in most cases, are described in the IPBES regional assessments. For instance, since 2005 in the Pacific region, locally managed marine areas have grown in number; in Madagascar, the NGO Blue Ventures is piloting payment schemes for blue carbon; and in West Africa, mangrove conservation has progressed in a six-country development project with local partners.

6.3.3.3.4 Building ecological functionality into coastal infrastructure

Given the inevitability of future coastal infrastructure development, it is vital that decision makers consider the ecological functions of coastal ecosystems from the start (Daffron *et al.,* 2015). Altered and damaged ecosystems are difficult to restore or rehabilitate, or not politically or economically feasible. Maintaining and managing natural system by removing stressors such as pollutants may be a fraction of the costs of restoration (Elliot *et al.*, 2007). In some cases, however, created ecosystems may even be culturally preferred. With the rapid increase in created coastlines, especially around urban areas, ecosystem rehabilitation, increasing attention has been paid to remediation and multi-purposing coastal structures such as breakwaters and marinas.

6.3.3.3.5 Engaging NGOs, industry and scientists as stakeholders to achieve common ecological and social good outcomes

Across countries, interpretations and awareness of the importance of conserving nature and its contributions to people in the oceans are diverse and dynamic, although a growing degree of convergence is emerging as a result of local social movements, global environment conventions and agreements, scientific efforts, and environmental advocacy. New national and local environmental NGO are emerging, creating greater and more distributed demands for conservation action. For instance, large international NGO have set up national branches and joint ventures in many countries, bringing their own concepts and values and adapting them to local circumstances and channels of influence. Although the translations do not always work, with time and experience, the short-term actions can mature to more appropriate forms for local ecosystems and species, values and knowledge, e.g., national versions of seafood consumption guides.

Powerful industry players may obstruct and even capture the political processes, e.g., port infrastructure, shipping, industrial fishing, tourism and real estate (Jenkins & Schröder, 2013; Bavinck *et al.*, 2017), but industry actors are also highly relevant to finding solutions. Options to involve private interests include corporate social responsibility, market-based instruments such as certification (e.g., seafood certification, 6.3.3.3.2) and best practice in fisheries and aquaculture production methods (Jenkins & Schröder, 2013). In the case of coastal hypoxia caused by nutrient loading, more attention is needed to engage sectors responsible for the largest point-source nutrient emissions (farmers, intensive livestock producers, agricultural chemical and fertilizers companies) in policy decision-making, remedial action, educational programmes and training sessions (STAP, 2011).

Marine assessment processes provide opportunities for management agencies, research institutes, NGO and other citizen groups to assess and report the status of nature and its contributions to people, to identify issues and suggest solutions. International collaboration on assessments and standards can enable national status reports to be shared and information to be aggregated and compared regionally and globally. In addition to international government organization assessments, such as the World Ocean Assessment, NGO and privately funded systems can contribute to collaborative efforts such as the Ocean Health Index (http://www.oceanhealthindex.org/).

6.3.4 Integrated Approaches for Sustainable Freshwater

Freshwater ecosystems include rivers, lakes, reservoirs, wetlands and groundwater systems. The options for decision makers discussed under this section are based on SDG6 (clean water and sanitation) and several Aichi Biodiversity Targets (ABTs). Population growth, climate change, increasing demand for water, institutional policies, and land-use change – all interact to determine available water supply and use (Liu *et al.*, 2013). Short and long-term options to manage water need integrated and adaptive governance that reduce pressures on water, encourage nature-based solutions and green infrastructure, and promote integrated water resource management as well as considerations of water-energy-food nexus (WWAP/UN-Water, 2018). Adaptive measures include rainwater harvesting, improved pasture management, water reuse, desalinations and more efficient management of soil and irrigation water, among others (Jiménez *et al.,* 2014). Inclusive and informed approaches to water governance open up opportunities for stakeholders with diverse interests to be involved in making decisions that are integrated, adaptive, resilient, innovative and responsive (WWAP, 2018; Ison & Wallis, 2017; Razzaque, 2009; Pahl-Wostl, 2007). Transformational change requires a move away from the business as usual approach and puts emphasis on the recognition and integration of multiple values, including intrinsic and relational values, in water management (WWAP/UN-Water, 2018; Bartel *et al.,* 2018).

The complexity of water resources is reflected in its status as an economic good as well as a public good (CESCR, 2003; Griffin *et al.,* 2013; Whittington *et al.,* 2013). It is well established that challenges to water management are aggravated as there are ambiguities in relation to the status and scope of legal rights governing access to water (McCaffrey, 2016; Murthy, 2013). It is critical to understand the combination of options and instruments that can be designed to meet policy objectives and allocations arrangements (WWAP, 2015; OECD, 2015). In the short-term, a clear legal status needs to be in place for all types of water, such as surface water, groundwater and wastewater along with a clear indication of the ownership and user rights and polluter duties. Such a legal regime will enable the responsible authority/ies to determine the level of access to be given to various users, monitor the losses in water distribution, impose sanctions such as fines or penalties, and determine the response measures in cases of exceptional circumstance, such as drought and severe pollution (Ring *et al.,* 2018; Acosta *et al.,* 2018; Stringer *et al.,* 2018; Scarano *et al.,* 2018; WWAP, 2015).

In many countries, environmental flow allocations continue to be used as a surrogate for the protection of Indigenous Peoples and Local Communities' interests in water management (e.g., NWI, 2004; DoW, 2006), with little or no consideration for IPLC customary rights of freshwater resources in water allocation decisions (Finn & Jackson, 2011; Bark *et al.,* 2012; Jiménez *et al.,* 2015). Low representation of IPLCs in water resource decision-making has often led to conflicts and disagreements over values and management priorities, which have often been aggravated by clashes between market-based instruments and local customary rights (Boelens & Doornbos, 2001; Boelens & Hoogendam, 2001; Trawick, 2003; Jiménez *et al.,* 2015) (Also see Supplementary Materials 6.3).

This section presents both short and long-term options for decision makers that contribute to integrated approaches to freshwater governance **(Table 6.5)**.

6.3.4.1 Improving water quality

***Setting clear water quality standards*:** Improved water quality standards are essential to protect both nature and human health, by eliminating, minimizing and significantly reducing different streams of pollution into water bodies (SDG6) including river basins **(Figure 6.4)**. Command and control regulations such as end-of-pipe control, quality standards and discharge permits have a significant role to play to reduce point source pollution (e.g., wastewater from households, commercial establishments and industries) (Kubota & Yoshiteru, 2010; UNEP, 2016; OECD, 2017; WWAP, 2017; WWAP, 2012). A strong and transparent implementing authority with necessary technical and managerial capacity as well as provisions on access to information that benefits implementation and enforcement processes would benefit such regulatory measure (UN-Water 2015b). In addition, mitigation of the impacts of pollution from non-point or diffuse sources (e.g., run-off from urban and agricultural land) requires ecological responses,

Table 6 5 Options for integrated approaches for freshwater governance.

Short-term options	Long-term options	Key obstacles, potential risks, spill-over, unintended consequences, trade offs	Major decision maker(s)	Main level(s) of governance	Main targeted indirect driver(s)
Improving water quality					
Setting clear water quality standards; data gathering & monitoring		• Identification of non-point sources • Lack of managerial and technical capacity	National sub-national and local government, private sector, IPLCs, civil society	National, sub-national, local	Institutions, governance, technological
Collaborative initiatives and IPLC monitoring		• Lack of adequate monitoring; • Lack of adequate or effective remedial action	Global, regional, national government, private sector, IPLCs, civil society, donor agencies, science and education organisations	All	Institutions, governance
Technological advances		• Lack of quality standards • Lack of institutional and financial capacity	Regional, national government, private sector, donor agencies, science and education organisations	All	Economic, technological
Strengthening standards for corporate sector		• Lack of compliance monitoring • Lack of enforcement	Global, regional, national government, private sector, donor agencies, NGOs	All	Economic, institutions, governance
Managing water scarcity					
Water abstraction charge		• Abstraction charge may not reflect the environmental cost and vulnerability of local population	National sub-national, local government; IPLCs, private sector, citizens (households, consumers), community groups, farmers	National, sub-national, local	Institutions, economic, governance, demographic
Restrict groundwater abstraction		• Lack of management plan for groundwater • Lack of (or weak) ownership right of groundwater • Lack of monitoring of data • Lack of policies harmonising groundwater with energy, agriculture and urban development policies	National, sub-national, local, private sector, IPLCs, citizens (households, consumers), community groups, farmers	National, sub-national, local	Economic, institutions, governance. demographic
Water efficient agricultural practices		• Lack of access to water efficient technologies for agriculture and optimized irrigation systems • Lack of technical assistance and finance	National, sub-national, local, private sector, farmers, IPLCs	National, sub-national, local	Technological, institutions, governance, economic
Engaging stakeholders					
Integrated, rights based, and participatory approach to water management		• Weak (or lack of) transparent process to identify relevant stakeholders • Weak provisions to access information by stakeholders • Ineffective participation of all stakeholders including IPLCs • Weak (or lack of) a right based approach to protect water resource • Inadequate regulatory framework to support custodianship and open access	National, sub-national, local government; private sector, civil society, IPLCs, donor agencies, science and education organisations	National, sub-national, local	Institutions, governance, cultural

Short-term options	Long-term options	Key obstacles, potential risks, spill-over, unintended consequences, trade offs	Major decision maker(s)	Main level(s) of governance	Main targeted indirect driver(s)
Use of economic instruments					
Payment for water ecosystem services		• Lack of quantifiable environmental objectives at the watershed level • Lack of evaluation of environmental additionality • Lack of monitoring of ecosystem services outcomes	National, sub-national, local government, civil society, IPLCs, private sectors, donor agencies	National, sub-national, local	Economic, institutions, governance
Improving investment and financing					
Public private partnership		• Ineffective regulation, monitoring • Lack of consideration of ILK and IPLC cultural values	National and local governments; civil society including communities, small farmers, workers, women, and IPLCs. Agribusiness, mining companies, finance capital, and international financial institutions	All	Economic, institutions, governance
Promoting Integrated Water Resource Management					
Fostering polycentric governance		• Fragmentation of instruments and institutions • Complexity of issues • Reluctance to move beyond traditional methods	National and local governments, IPLCs, Civil Society, private sectors	Regional, national, sub-national, local	Economic, governance, institutions
Facilitating integration across sectors		• Acknowledge water-food-energy nexus • Broadening the knowledge base	National and local governments, IPLCs, Civil Society, private sectors	Regional, national, sub-national, local	Economic, governance, institutions, technological
Harness international normative framework		• Lack of compliance and implementation	National and sub-national government	Regional, national, sub-national, local	Economic, governance, institutions
Encouraging transboundary water management					
Implementing international law norms and basin treaties		• Lack of political will • Fragmentation • Lack of funding • Lack of implementing mechanisms and institutions	• Treaty Secretariats • National and Supra-national governments • Non-state actors such as NGOs, private sectors, individuals	Global, international, national	Economic, institutions, governance, regional conflicts
Addressing fragmentation		• Lack of political will • Lack of implementing institutions	Treaty secretariats, National supra-national governments	Global, regional, national	Governance, institutions
Strengthening participatory tools		• Lack of information • Lack of effective consultation and participation; • Weak institutions to promote co-decisions • Lack of monitoring	Treaty secretariats, national and supra-national governments	Global, regional, national	Governance, institutions

and education and awareness programmes (OECD, 2017). A basin wide programme can play a positive role in reducing run-off from agriculture (UNEP 2016; GEO6 Freshwater). Moreover, nature-based measures on water purification, soil erosion, urban stormwater run-off, flood control can effectively promote green infrastructure (WWAP/UN Water 2018; Also see section 6.3.5.3).

Collaborative initiatives: The countries with shared water may develop and enforce water quality standards through international or inter-state agreements (GEO-6 Freshwater, 2017). Agreements managing transboundary water can identify highly contaminated sites, develop and implement remedial action and monitoring, and contribute to measurable improvements in the water quality (GEO-6,