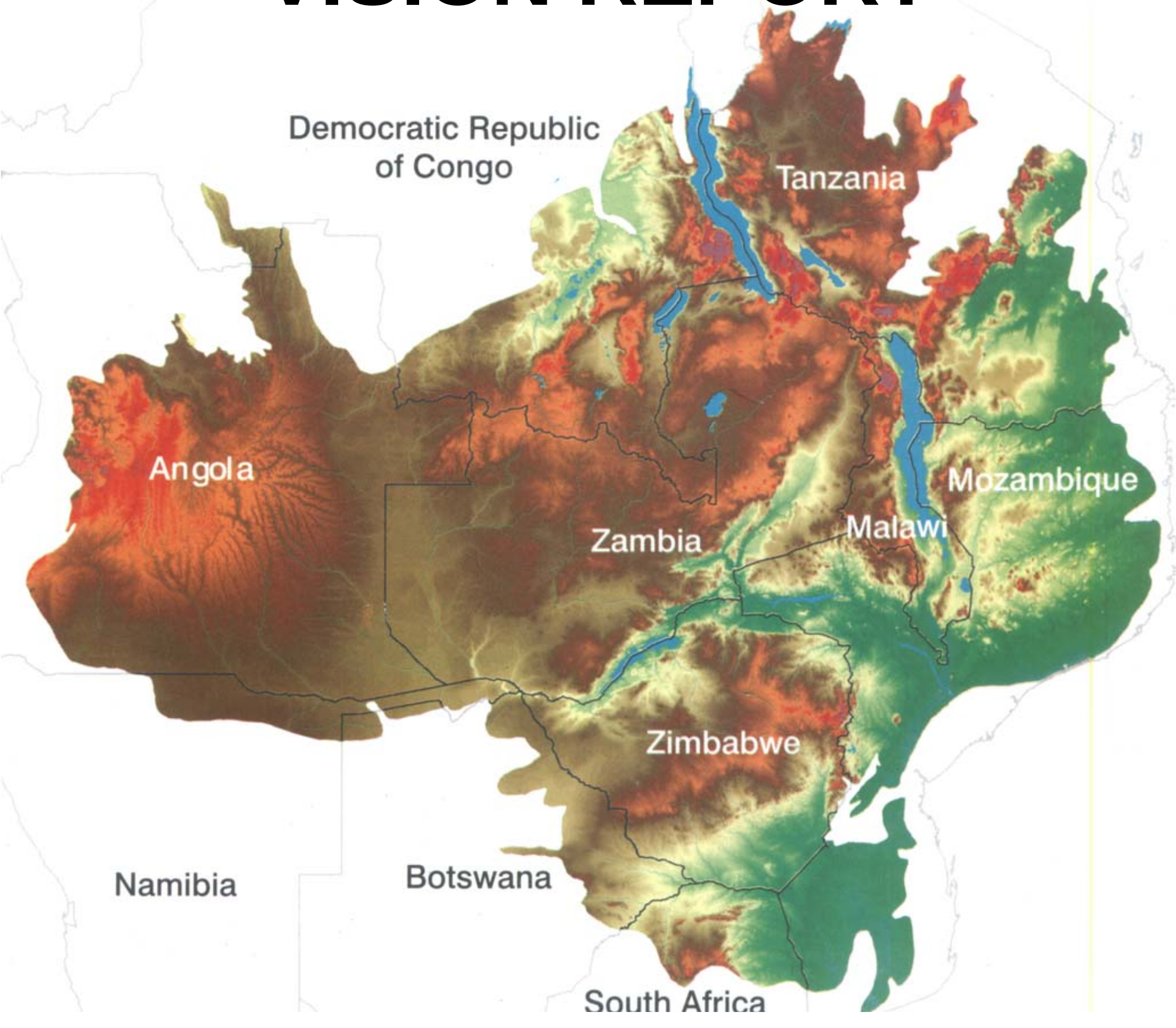
MIOMBO ECOREGION VISION REPORT



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December 2001 (published 2011)

Occasional Publications in Biodiversity No. 20

WWF - SARPO

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VISION REPORT

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(revised August 2011)

by

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PREFACE

The Miombo Ecoregion Vision Report was commissioned in 2001 by the Southern Africa Regional Programme Office of the World Wide Fund for Nature (WWF SARPO). It represented the culmination of an ecoregion reconnaissance process led by Bruce Byers (see Byers 2001a, 2001b), followed by an ecoregion-scale mapping process of taxa and areas of interest or importance for various ecological and bio-physical parameters. The report was then used as a basis for more detailed discussions during a series of national workshops held across the region in the early part of 2002. The main purpose of the reconnaissance and visioning process was to initially outline the bio-physical extent and properties of the so-called Miombo Ecoregion (in practice, a collection of smaller previously described ecoregions), to identify the main areas of potential conservation interest and to identify appropriate activities and areas for conservation action.

The outline and some features of the Miombo Ecoregion (later termed the Miombo–Mopane Ecoregion by Conservation International, or the Miombo–Mopane Woodlands and Grasslands) are often mentioned (e.g. Burgess *et al.* 2004). However, apart from two booklets (WWF SARPO 2001, 2003), few details or justifications are publically available, although a modified outline can be found in Frost, Timberlake & Chidumayo (2002).

Over the years numerous requests have been made to use and refer to the original document and maps, which had only very restricted distribution. Now, 10 years after the original draft Vision Report was produced, we are making the report more widely available as a Biodiversity Foundation for Africa (BFA) publication. Only minor corrections or additions have been made to the original document, and maps from other publications have been added in.

Another BFA Publication (No. 21, Timberlake *et al.* 2011) presents a series of maps showing the areas of biological importance, an output from a BFA consultancy.

ACKNOWLEDGEMENTS

We would like to acknowledge the support of WWF SARPO in Harare, particularly Fortune Shonhiwa, Programme Office for the Miombo Ecoregion visioning process. The maps were mostly produced by WWF's GIS Unit.

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1. INTRODUCTION

The mission of the World Wide Fund for Nature (WWF) is the conservation of nature and the promotion of sustainable use of natural resources. Historically, the strategy of WWF was largely based on single species, often driven by the need to respond to dramatic poaching levels of well-known animal species and to address severe cases of habitat degradation and loss all over the world. While these campaigns were entirely legitimate, they may have inadvertently under-emphasized some fundamental conservation imperatives such as conservation of large-scale ecological processes, maintaining viable populations of species, addressing habitat representativeness and ecosystem diversity. After reviewing the present challenges and lessons of conservation projects over the last 50 years, WWF International has decided that an ecoregion approach is the most appropriate to set conservation targets and priorities at a continental or worldwide level. This culminated in the determination of ecoregions across the world (Olson *et al.* 2001), with around 120 in Africa, and the selection of the Global 200 most important ecoregions (WWF 1999).

As part of this approach, the WWF Southern Africa Regional Programme Office (WWF-SARPO) has embarked on an ecoregion conservation programme for the Miombo (or Southern Caesalpinoid Woodlands) Ecoregion. This is one of the Global 200 ecoregions, the largest of 21 on mainland sub-Saharan Africa. The ecoregion provides a good example in which management of hydrological processes is central to maintaining its essential features, such as soil moisture regimes, dominant vegetation cover, characteristic species and associated evolutionary processes. In this regard, the sustainable management of water, involving the wise use of ubiquitous dambos (broad, seasonally-inundated drainage lines on the plateau) and the protection of major river catchments located in the deep aeolian Kalahari sands of Angola and Zambia, is crucial to ecological functioning. The goal of this programme is to contribute to the maintenance of biodiversity and functioning ecosystems in the Miombo Ecoregion for the benefit of people and nature, while the purpose is to extend that part of the ecoregion where biodiversity conservation and functioning ecosystems are fully incorporated into landuse practices, to the benefit of conservation of both agricultural lands and wildlands.

1.1 Ecoregion Conservation

Ecoregion conservation enables WWF to take a more comprehensive approach to biodiversity conservation without sacrificing sensitivity to local biodiversity issues and socio-economic conditions. This larger-scale, more integrated approach enables WWF to better assess both the proximate and root causes of biodiversity loss, and to design policy and management initiatives at appropriate levels from international trade policies to site-specific protected area management or community development projects. Moreover, it allows WWF to connect what it does at the local level with what needs to be done at national and international levels, to better link field work with policy work, and to build new partnerships in carrying this out.

An ecoregion is defined as a relatively large unit of land or water that is biologically distinct from its neighbours, an area that harbours a characteristic set of species, communities, dynamics and environmental conditions. It embodies the general principles of ecosystem conservation and the major goals of conservation biology since it encompasses: (a) the representation of all broadly distinct broad communities and species assemblages, (b) the maintenance of viable plant and animal populations within large expanses of intact habitat, (c) special recognition of keystone ecosystems, habitats, species and phenomena, (d) conservation of large scale ecological processes, and (e) conservation of species of special concern. It differs from other approaches in that it demands a visionary and strategic view in planning to conservation, it operates over large temporal and bio-geographical scales, and it requires an understanding of social and biological processes and dynamics operating at these scales. It is usually viewed in the long-term context of 50 years. The broad spatial and temporal scale adopted requires an integrated and multi-disciplinary approach where biological units are the basis for planning and activities. As an ecoregion unit may cross political boundaries, thinking must extend beyond national boundaries or programmes, even though requisite conservation actions happen nationally. The challenge is therefore to operate over these large spatial scales through coordinated and concerted actions across political boundaries. Although with many attendant difficulties, the often cross-boundary nature of the approach is vital to achieving long-term ecosystem conservation goals.

1.2 The Miombo Ecoregion

The Miombo Ecoregion, covering over 3.6 million square kilometres across 11 countries of southern Africa (Figure 1), comprises dry and moist woodlands that support some of the most important thriving large mammal populations left in Africa. Black rhinoceros, African elephant, African hunting dog, Cheetah and the Slender-nosed crocodile are some of the threatened species, along with many less-known species of plant, birds, reptiles, fish and insects. More than half of the estimated 8,500 plant species in this ecoregion are found nowhere else on Earth. There is also a distinctive bird, reptile and amphibian fauna.

One of the region's main characteristics is the presence of large expanses of rolling savanna woodland on a gently undulating plain, interspersed with grassy drainage lines (dambos) in a regular catenary sequence. The pattern is distinct and repetitive. It is the juxtaposition of different vegetation types – nutrient poor and nutrient-rich woodland, areas of short nutritive grasses interspersed with taller rank grass, wetlands in an otherwise dry environment – that allows many of the large herbivores to survive. The herbivores move through the landscape seasonally, making the best use of forage resources in what is generally a nutrient-deficient and low carrying-capacity environment. In many respects, conservation of these woodlands needs to focus on broad landscape-level processes and hydrology rather than on specific habitats or species.

The ecoregion is typified by a dominance of deciduous woodland composed of broad-leaved trees of the legume subfamily Caesalpinioideae. Owing to the deciduous nature of the woodland there is a well-developed grass layer which, in turn, gives rise to frequent and wide-spreading fires. Caesalpinoid woodlands are confined to the gently undulating, unrejuvenated Central African plateau at an altitude of 800–1200 m, although they come down to the coastal plain in Mozambique and Tanzania. The ecoregion is incised by the large river valleys of the Zambezi, Luangwa and Limpopo, and by the Rift Valley lakes of Tanganyika and Malawi. A number of major drainage basins such as the Zambezi, Limpopo, Save, Cuando, Kavango, Rufiji, Rovuma and Luapula (part of the Upper Congo) are incorporated.

Although the ecoregion is commonly termed the Miombo Ecoregion, this is confusing as the Caesalpinoid woodlands which it comprises extend significantly beyond true miombo woodland.

A unimodal rainfall pattern with distinct and prolonged dry seasons, coupled with the generally leached and impoverished soils, are major features. It is the combination of environmental factors– rainfall, length of dry period, soil nutrient status and fire – which is the probable main determinant of woodland limits and separates this from adjacent ecoregions.

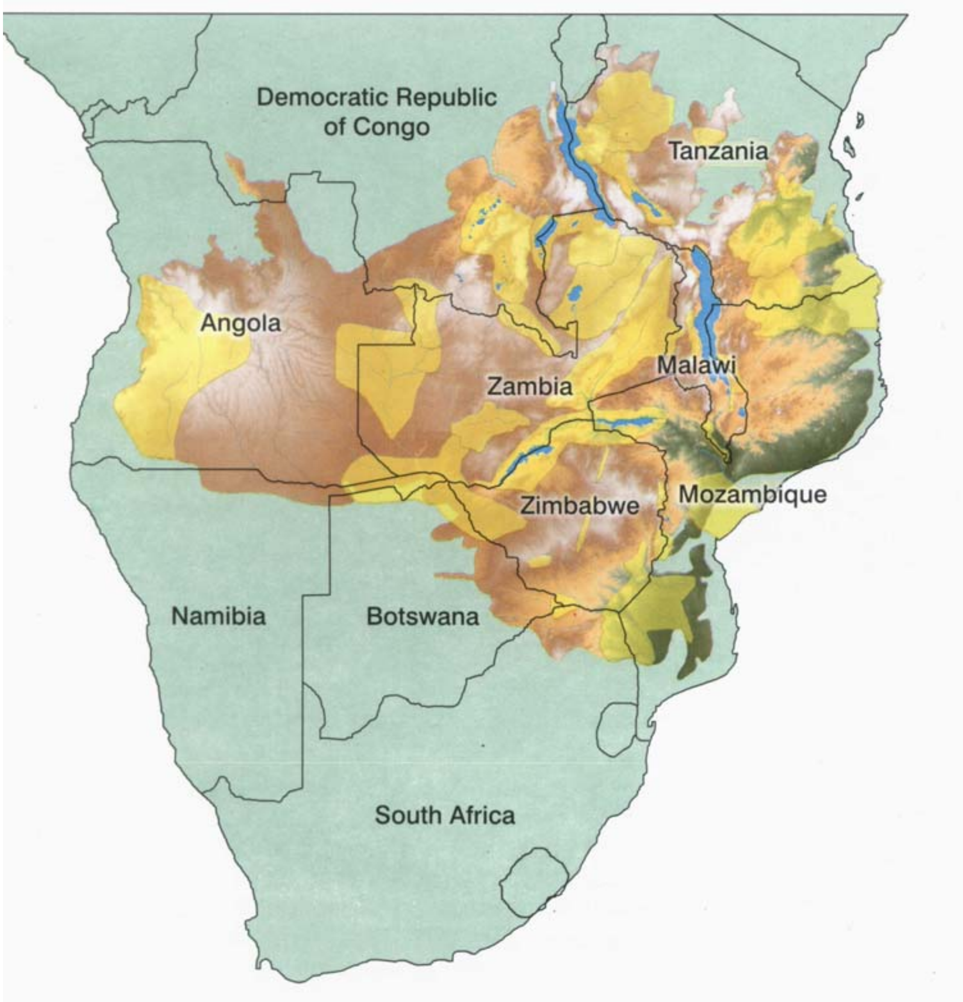

Figure 1. The Miombo Ecoregion and southern Africa (from WWF SARPO 2003).

The primary and direct impacts on the ecoregion come from the large and rapidly growing human population and its demand for agricultural land. Large areas of dry woodland, unlike moist forests, can be more easily converted to agricultural land owing to the lower above-ground woody plant biomass, though the social and environmental consequences are probably as profound as with moist forest.

Most of the miombo savanna woodlands are inhabited, and there are few areas that can be considered at all pristine. Many rural people depend heavily on natural resources for their livelihoods. These conditions have led to a strong emphasis on the sustainable use of natural resources in the region, and on Community-based Natural Resource Management (CBNRM) programmes. The region is considered by many to be a global model for CBNRM. As other organisations besides WWF are involved in natural resources management and conservation initiatives within the ecoregion, WWF's planning process will require collaboration with a range of partners.

The Miombo Ecoregion is exceptionally large compared to many others, and also diverse. Although it can be split into a number of sub-regions (for example, Burgess *et al.* 2004), it was felt that its integrity should be retained, as it is this that gives rise to its uniqueness and importance. In some ways it could be said that conservation of the Miombo Ecoregion is more about conservation of processes operating at a landscape scale across thousands of square kilometres than about conservation of species or individual habitats.

1.3 The Ecoregion Conservation Planning Process

The first step in the ecoregion conservation planning process is a **reconnaissance** to outline the current state of biological and socio-economic knowledge for the area and to identify major gaps. This stage involves a certain amount of data gathering and **assessment**. The reconnaissance also seeks to identify major factors influencing environmental change and loss of biodiversity, to identify key problems and opportunities for conservation interventions, and to provide a basis on which to plan a more comprehensive biological and socio-economic assessment.

Both the reconnaissance and subsequent assessments provide the basis for developing a biodiversity conservation **vision**. The vision should set out long-term goals for conservation of the ecoregion's biodiversity, identify key sites, populations and ecological processes. It should guide the development of the action plan and any strategic decisions as circumstances and opportunities change. This is followed up by the development of a **conservation action plan**. The action plan sets the 10 to 15 year goals for conservation of the ecoregion's biodiversity, and identifies the actions needed to achieve those goals. It is a comprehensive blueprint for conservation action, and identifies the first steps on the road to achieving the vision.

1.4 Miombo Ecoregion Vision Report

This report has built upon the reconnaissance process and vision building workshop to produce a biodiversity vision. This vision is essentially a statement coupled with a series of biologically important areas that have been identified for special attention. These areas have been identified and mapped, and are described in this report. The expectation is that if we concentrate our conservation efforts on them with full recognition of the goals of biodiversity conservation, we should eventually realize our long-term biodiversity vision.

The Vision Report is a further step in the ecoregion planning process. It has built upon the reconnaissance process but has advanced by producing a set of biologically important areas across the ecoregion in a participatory process that involved biologists and socio-economic experts. These areas represent overlaps in the occurrence and distribution of key taxa, species and genera and in some cases, ecological processes. Boundaries of some of these areas are still tentative, hence further refinement and detailed biological and associated socio-economic assessments will be needed, along with identification of opportunities for conservation.

The major ecological processes identified during the reconnaissance and vision workshops have also been described, as are the major socio-economic opportunities and threats. It is worth stating that in this process an attempt was made to map out socio-economic processes, which will need to be seriously considered in the construction of conservation action plans.

The report sets out to give an overview of the Caesalpinoid Woodland (Miombo) Ecoregion, and to describe its boundaries, biological and socio-economic attributes. Particular attention has been given to species diversity, regional endemism, global significance and to the ecological processes that both underpin and unify the ecoregion. Suggestions for further necessary short-term activities are also described.

2. PHYSICAL FEATURES AND PROCESSES

2.1 Extent and Physical Determinants

The Miombo Ecoregion covers over 3.8 million km^2 in central and southern Africa, extending from the west coast in Angola to the east coast in Mozambique and Tanzania. It includes all or part of 11 countries – Angola, Namibia, Botswana, South Africa, Zimbabwe, Zambia, Democratic Republic of Congo (DRC), Mozambique, Malawi, Tanzania and Burundi. Much of the ecoregion is on the ancient African plateau with an altitude of 800 to 1250 m above sea level, but in the east the ecoregion transcends the escarpment and elements of the ecoregion can be found in the east African coastal zone, at 200 to 300 m altitude (Figure 2). In spite of the favourable elevation, the biological elements of the ecoregion give way to other biomes in the northeast, south and southwest. Elevation therefore does not fully determine the Miombo Ecoregion boundary.

Overall, the Miombo Ecoregion boundary appears to be determined by the interaction of topography, precipitation and temperature. Climate is probably the most important determinant. The ecoregion occurs in the unimodal rainfall zone, except in the northeast in central Tanzania where rainfall tends to be bimodal. Mean annual rainfall is in the range of 600 to 1400 mm (Figure 3) and occurs from November to April. To the northwest, the boundary roughly follows the 1400 mm isohyet while to the northeast and south, the boundary follows the 600 mm isohyet. It is obvious that the biological elements of the ecoregion are ill-adapted to humid and arid conditions. In central and southern Africa both humid and arid conditions are associated with mean maximum temperatures higher than 30^{o}C. Much of the region therefore lies in the warm subhumid zone with a mean maximum temperature of 24–27^{o}C.

2.2 Geology

The geological foundation of much of south and central Africa consists of large, stable, Archaean crustal blocks called cratons, of relatively low metamorphic grade, separated by broad zones of more highly metamorphosed rocks known as mobile belts. The cratonic nuclei include the Congo, Tanzania, Kaapvaal and Zimbabwe cratons; dating indicates a long and complex geological history and gives ages ranging from around 3500 to 2600 million years (Ma). Cratonic stabilisation did not occur everywhere at the same time. In the Zimbabwe craton, which is the best exposed, some early stabilisation had been effected by 3300 Ma with final stabilisation at about 2600 Ma, accompanying the emplacement of vast volumes of potassium-rich granites.

The cratons now consist of the deformed remains of volcano-sedimentary piles (greenstone belts) intruded by various, and numerous, granites. Metamorphic grade in the greenstone belts is such that primary textures and structures are often well preserved and the primary nature of the rocks is clear. For example, basaltic lavas dominate the volcanic pile and numerous examples of pillows indicate that eruption occurred under water. Also pockets of limestone, although now recrystallised, show fossil stromatolites in places indicating that, here at least, water depths were shallow. Typically, the basaltic greenstones weather to give fertile, reddish soils. Prominent among the associated chemical sediments are banded iron formations and ferruginous cherts, which often outcrop as prominent well-wooded ridges.

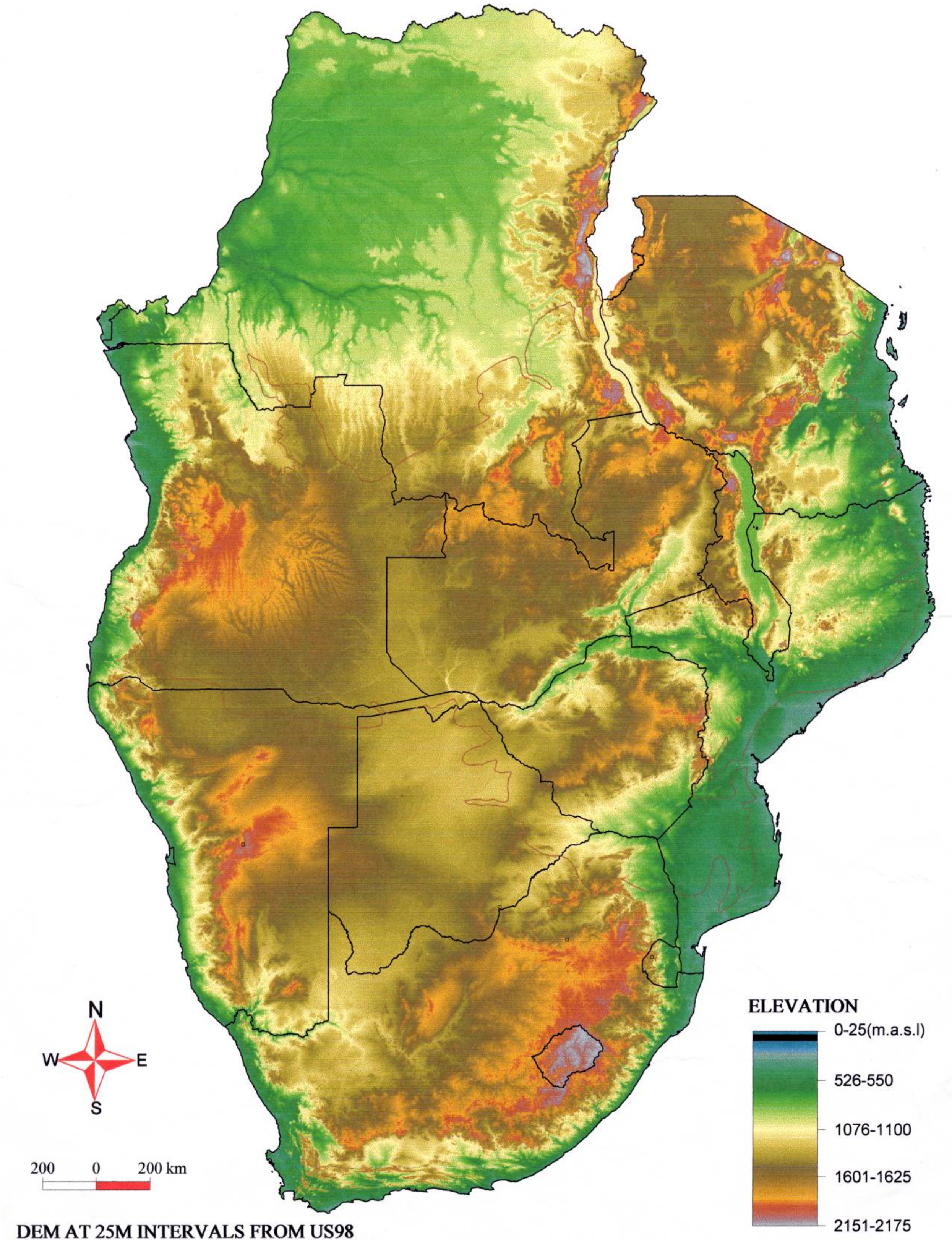

Figure 2. Southern Africa – physiography and altitude.

The mobile belts range from late Archaean to early Palaeozoic, with age groupings around 2700 Ma, 2000–1800 Ma, 1400–1100 Ma and 950–450 Ma. In places they show evidence of metamorphism and deformation of more than one age. Rocks include granitic gneisses, metasediments and metavolcanics all at high metamorphic grade. Perhaps the oldest of these, the well-documented but still enigmatic Limpopo Belt, separates the Zambezi craton from the Kaapvaal craton to the south. It consists of a central zone of Archaean metasediments, with a major development of quartzites, flanked to the north and south by high grade rocks of the adjacent cratons. Metamorphism and tectonism is late Archaean, at around 2700 Ma, followed by a second, early Proterozoic, phase at 2000 Ma.

Emplaced at 2580 Ma, and affording a magnificent marker for the end of the Archaean and the beginning of the Proterozoic, is the Great Dyke of Zimbabwe. Funnel-shaped in cross-section in its present erosion plane, it is not a true dyke but a NNE-trending line of contiguous, elongate, mafic/ultramafic, layered intrusions that almost bisects the craton. Gabbroic rocks form the upper part and ultramafic rocks, mainly pyroxenite and dunite, the major and lower part of the layered sequences. Weathering of the dunite has produced a surface serpentisation and nickel-rich soils that characteristically support unique, nickel-tolerant vegetation.

Proterozoic sedimentary and volcanic rocks of various ages occur intermittently overlying the Archaean cratons. Most of these extend into the marginal Proterozoic mobile belts to become highly deformed and metamorphosed; in places they have also been thrust over the adjacent cratons during the deformation. Among these is the early Proterozoic Magondi Supergroup of basalts, quartzites, dolomitic marbles and metapelites, deposited on the NW side of the Zimbabwe craton. Orogeny around 2000–1800 Ma produced the Magondi Mobile Belt, involving the deformation of the Magondi rocks and underlying basement. On a larger scale, this is part of more widespread orogenic events affecting southern, central and eastern Africa at this time. On the northern flank of the Zimbabwe craton, the various metasediments and infolded basement of the Zambezi Belt were extensively deformed around 850 Ma. The belt cuts across the earlier Magondi Belt and extends west into southern and central Zambia to the Copperbelt. Eastwards it links with the N-trending Mozambique Mobile Belt, which straddles Zimbabwe's eastern international border with Mozambique and extends northwards as a major structural zone into Zambia, Tanzania and Uganda. In eastern Zimbabwe, the late Proterozoic Umkondo Group forms a cratonic cover of quartzites, shale and minor volcanics, and extends eastwards to become an integral part of the Mozambique Belt.

Cratonic granite-greenstone terrains, mobile belts and cratonic cover rocks together form the Precambrian Basement platform on which the Phanerozoic rocks were deposited. This basement is host to economically important minerals – gold in the Archaean greenstone belts; chromitite and platinum group minerals in the Great Dyke; and copper in the Proterozoic, especially in the Copperbelt of Zambia and Katanga Province of the DRC.

The most conspicuous rocks of Phanerozoic age in south and central Africa belong to the Karoo Supergroup. These were deposited on Gondwanaland from the late Pennsylvanian (Upper Carboniferous) to Jurassic Periods, a span of some 100 Ma, as this giant continent moved slowly across the South Pole and thence northwards to straddle the Equator before splitting to form the continents that are familiar today. The sequence of sedimentation in the intracontinental basin, from all the modern component fragments, reflects the steadily changing climate from frigid to cool temperate to warm temperate to hot desert. Finally, cracks opened across Gondwanaland and permitted the eruption of the vast numbers of basalt flows that constitute the uppermost part of the Karoo Supergroup. Thereafter the modern continents moved to their present positions.

In Africa, Karoo rocks can be traced from extensive areas across South Africa to Namibia, Botswana, Zimbabwe (particularly Matabeleland and the Zambezi Valley), Zambia and small patches in Malawi, Tanzania and Kenya. Lower Karoo rocks, deposited during the glacial and cool temperatures, are principally shales and sandstones with coal derived from *Glossopteris* flora. The basal formation is a tillite, which commonly rests on a glaciated pavement – the Pre-Karoo erosion surface.

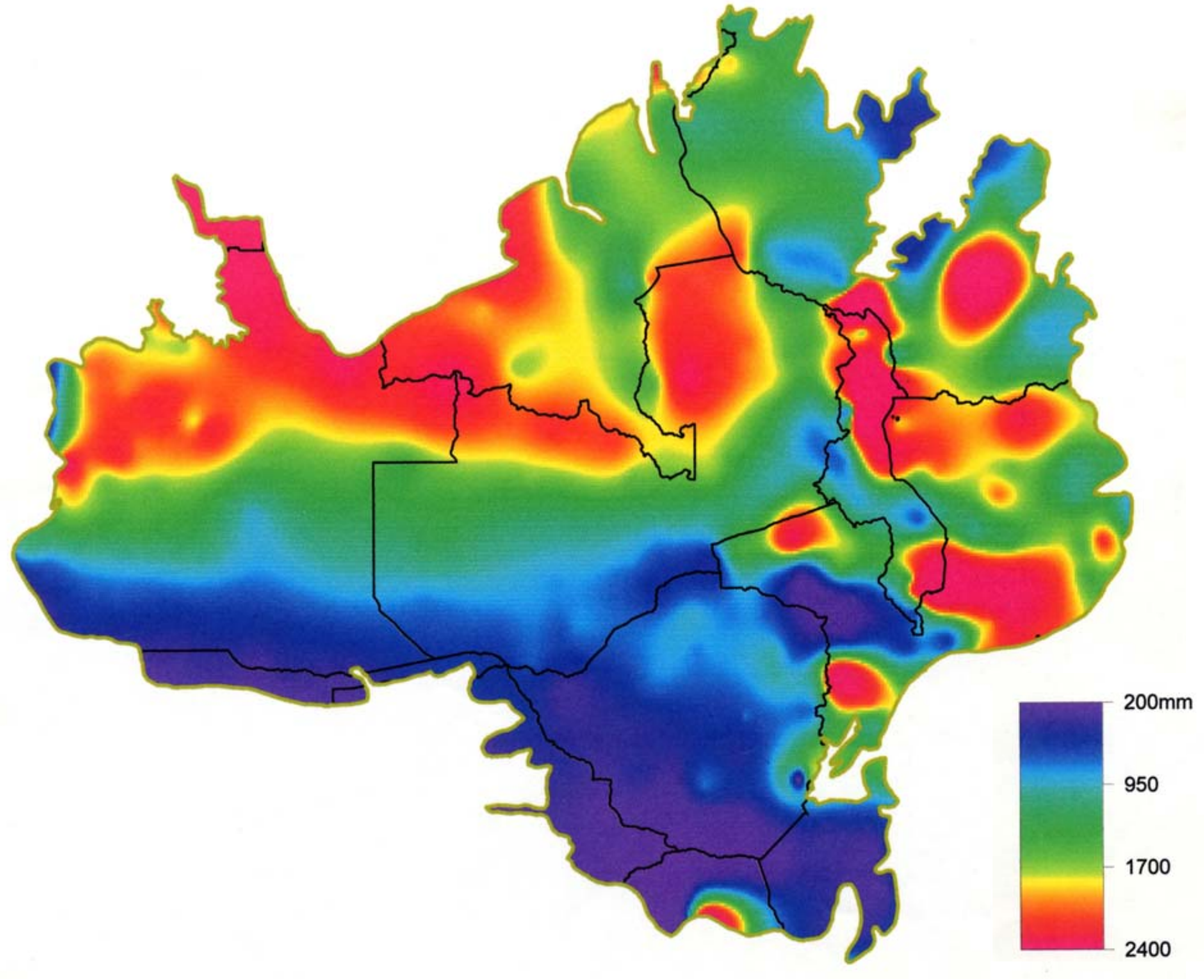

Figure 3. Miombo Ecoregion – rainfall.

Upper Karoo sediments are lighter-coloured grits, sandstones, shales and mudstones that contain Permian therapsids, Triassic dinosaurs and a variety of plant fossils. Some of the finer grained rocks are highly erodible, and in certain localities in Hwange National Park, the floor of the Zambezi Valley and south of Harare exhibit spectacular gully and sheet erosion. The basalts can be seen today in Lesotho, the Limpopo Valley, Victoria Falls and smaller outliers elsewhere.

The break-up of Gondwanaland produced new coastlines along the eastern and western margins of Africa, and Cretaceous and Cainozoic times are recorded by littoral sediments associated with shoreline fluctuations. In the hinterland, however, the Kalahari and Congo basins have been the loci of continental deposition. The most recent deposits are the Kalahari Sands which date from the Miocene Epoch and which have been blown repeatedly, in various directions, until the present day. Deposits of these sands now occur far beyond the present Kalahari region, in scattered patches through Zimbabwe and Zambia, and locally provide the uppermost soil for the Miombo Ecoregion. The underlying geology of the ecoregion covers a wide spectrum of rock types ranging in age from Archaean onwards but, in itself, does not control the distribution of the Caesalpinoid woodlands.

2.3 Landscape Evolution

The landscapes in the Miombo Ecoregion are dependent mainly on the geology, climate and drainage, and usually have taken many millions of years to reach the present-day stage.

The geological control is effected by the relevant resistance to weathering that the different rock types exhibit. Thus more resistant rocks, such as sandstones, quartzites and ironstone formations, are located along ridges and other high-standing areas, whereas soft rocks, such as shales and mudstones, occur in low-lying positions. Certain rock types weather to characteristic landforms. For example, the granite terrain, seen widely across Africa, shows curved exfoliated domes (bornhardts) and rectangularly jointed blocks (tors and inselbergs).

Climate controls both temperature and rainfall, the latter producing the water essential for chemical weathering. Much of southern Africa, including the Miombo Ecoregion, experiences a marked dry season – wet season climatic regime, which leads to pediplanation as the dominant geomorphic process.

Drainage governs the movement of water and soil particles to lower levels, ultimately to sea level. Incision of the river valleys provides the original 'notch' on the ground surface, from which pediplanation can advance.

Pediplanation entails the retreat of hill slopes as rock is weathered and removed from the steepest slopes, with resultant advance of the lower pediment and concomitant diminution of the higher pediment. With the passage of time the areas at the higher level are reduced to become residuals (inselbergs) while the lower pediments coalesce to form pediplains (erosion surfaces). The erosion surfaces that can be traced throughout Africa south of the Sahara are: Pre-Karoo (300–200 Ma), Gondwana (170–135 Ma), Post-Gondwana (135–100 Ma), African (100–24 Ma), Post-African (24–5 Ma), Pliocene (5–2 Ma) and Quaternary (<2 Ma).

The geological age assigned to each erosion cycle is that time in earth history during which base level was sea level. As succeeding cycles followed, the pediplanation processes continued but reflected the earlier appropriate base level.

Within the Miombo Ecoregion there are numerous occurrences of the Pre-Karoo erosion surface around the margins of Karoo Supergroup rocks, but these are insignificant compared with the dominance of sub-aerial, younger erosion surfaces. The vegetation correlates with the African and Post-African surfaces that lie at altitudes of 1000 to 2000 m. Lower levels within the Miombo Ecoregion, such as the Zambezi, Luangwa and Limpopo valleys, are the result of the Pliocene erosion cycle advancing and destroying the higher, Post-African erosion surface. The dominantly Mopane vegetation, which requires a hotter, drier environment, is suited to the climatic regime at altitudes of less than 1000 m and commonly 500 to 800 m (Lister 1987).

An offshoot of the Miombo Ecoregion occurring on the coastal plain of southern Mozambique is clearly outside the above parameters. The geomorphology here, through Cainozoic time to the present day, has been a scene of receding coastline and increasing width of the coastal plain which exhibits mainly sand deposits in dunes and sheets.

2.4 Hydrological Processes

A large part of the ecoregion is drained by the Zambezi River system that discharges into the Indian Ocean through Mozambique. Other rivers draining into the Indian Ocean are the Rufiji and Rovuma in southern Tanzania and Save and Limpopo in Zimbabwe and Mozambique. In the northwest the ecoregion is drained by the Congo River, the headwaters of which comprise the Chambeshi–Bangweulu–Luapula system in northern Zambia. The gradient in the headwaters of the Congo and Zambezi is low and extensive floodplains and swamps occur, such as the Bulozi floodplain in western Zambia, Bangweulu swamps, Lukanga swamps and Kafue Flats in central Zambia. The Luangwa is an exception, with its steeper gradient. Consequently there are no significant swamps along the Luangwa River. The tailwaters of the major rivers draining into the Indian Ocean have steeper gradients and therefore have fewer, if any, expansive wetland areas, apart from in their deltas which are outside the ecoegion.

The distinctive drainage and hydrological characteristics are determined by three factors: the seasonal distribution of rainfall, the spatial distribution of surface water and the gradient of the plateau surfaces.

2.4.1 Rainfall Processes

The three main airstreams affecting the rainy season in the ecoregion are the Congo airstream, the south-east trades and the northeast monsoons (Davis 1971). The Congo air originates partly from the southeast trades of the South Atlantic ocean which curve inland over the Congo Basin as they approach the equator and reach the Miombo Ecoregion from the northwest. This air stream is very humid in its lower levels and can produce widespread rain when subjected to convergence. The south-east trades of the south Indian Ocean hold more moisture during the summer months (November to April) and bring rains to the northeastern portion of the ecoregion, especially in Tanzania where rainfall tends to be bimodal. The northeast monsoon originates in the Asiatic high pressure system and may bring rain to the eastern portion of the ecoregion in summer.

Most of the rainfall occurs near the margins of the Inter-Tropical Convergence Zone along the Congo Air Boundary and at the northern limit of the southeast trades. Consequently, rainfall decreases from north to south across the ecoregion, except for areas at higher altitude and those in the proximity of lakes and swamps, both of which receive above-average rainfall compared to the surrounding areas. The rainy season is about 200 days in the north and 100 days in the south and valleys, such as the mid-Zambezi. However, there are substantial annual variations in the duration and amount of rainfall.

2.4.2 Characteristics of the Plateau Surface

The gently sloping plateau landscape that characterises the ecoregion has given rise to a sluggish, very widely-spaced drainage system. Drainage of the low plateau interfluves is probably effected mainly by sheet flow. Infiltration may account for a considerable proportion of the rainfall, especially in areas of Kalahari sands in the southwestern portion. The characteristic feature of the drainage in the headwaters of the plateau streams is the broad, shallow linear depressions known as dambos which may retain water and maintain streamflow well into the dry season. Dambos cover 10 to 15% of the area in the headwaters of the Zambezi and Congo, and about 5% in the middle waters of the Zambezi (Byers 2001a). The sluggish drainage has also given rise to expansive wetlands in the headwaters of the major rivers that are important habitats for wildlife and fish.

2.4.3 Spatial Distribution of Surface Water

One characteristic feature of rainfall of the ecoregion is its high inter-annual variability. The coefficient of variation which is a measure of this variability decreases with increase in rainfall. Thus areas with low rainfall have highly variable rainfall. This coefficient varies from 35% in the southern parts of Zimbabwe that receive about 400 to 600 mm per year, to 25% along the central watershed which receives 700 to 900 mm per year. In Zambia the coefficient of variation ranges from 30% along the mid-Zambezi valley to 15% in the northern high rainfall belt. Most of Malawi has a coefficient of variation between 20 and 25%.

Because of seasonal rainfall (November–April), peak flow occurs during February in the headwaters of the major rivers and as late as May in the tailwaters, well after the end of the rainy season. Most small streams dry up during the dry season while in larger streams flow is a small fraction of the wet season discharge. As there is virtually no rainfall in the dry season, streamflow is maintained by baseflow. Rainfall that contributes to streamflow and ground water recharge decreases from north to south across the ecoregion. Most of the discharge of the main rivers draining into the Indian Ocean is therefore derived from the wetter northern parts and is crucial to the maintenance of the East African Coast Ecoregion.

2.4.4 Soil–Water Processes

The plateau soils in the Miombo Ecoregion are of eluvial origin on basement quartzites, schists and granitic rocks. They are heavily leached and are poor in nutrients due to low organic matter, nitrogen and phosphorus content. This has arisen partly because of the poor acidic bedrock from which these soils are derived and partly due to the long period of weathering and leaching. These nutrient poor (dystrophic) soils have a low pH and high iron-aluminium toxicity, and range from sandy loam to sandy clay. As a result of the eluviation process, the clay content in the soil increases with depth, although most soils are generally shallow with a lateritic horizon. In areas of active erosion, such as escarpments, the topsoil is continuously removed, thereby exposing the lateritic material and/or bedrock.

Topsoil (0–30 cm) moisture content varies from <5% in the dry season to 10–20% in the rainy season, while the subsoil (>50–70 cm) moisture content remains >10% throughout the year (Chidumayo 1997). This seasonality in topsoil moisture has implications for primary production by shallow-rooted plants. Plateau soils also show a fertility gradient from the high rainfall areas with poorer soils in the north to areas with low rainfall and relatively more fertile soils in the south.

Low-lying areas, such as valleys, are run-on areas and have alluvial soils that are relatively more fertile (eutrophic). Landscape heterogeneity in the ecoregion has created a gradient in soil fertility between plateau landscapes and their adjacent valleys. Although low-lying areas receive less rainfall, this is augmented by run-off from the surrounding escarpments and/or plateaux that also sustains the alluviation process. Soil moisture regimes and fertility status are thus more favourable for primary production in valleys. This edaphic gradient also occurs at intermediate scale on the plateau landscapes where run-off from interfluves improves the soil moisture regime of run-on areas, such as dambos. At a small-scale, termite mounds also discharge run-off onto the surrounding area thereby creating mounds with deficient soil moisture, especially in drought years. Mound-building termites move the subsoil that has a higher clay content onto the land surface. Because of this engineering work, termite mounds have soils that are more clayey than those of the surrounding areas, although their nutrient status may not necessarily be higher. All these soil-water processes create heterogeneity at different landscape scales and produce a variety of habitats in the Miombo Ecoregion that support differing biological communities.

2.5 Biophysical Processes

Although the major tectonic processes on the Central African plateau ended more than 2 million years ago, geomorphological processes are still active today in the ecoregion and are controlled primarily by rainfall (Cole 1963). Geomorphological processes are continuously modifying the relief and drainage, soils and micro-climate, thereby creating conditions more favourable for some plants and less favourable for others. In turn, this brings about the extension of some vegetation communities and the recession of others of which only relicts may remain in the future. The Central African plateau of the Miombo Ecoregion is being dissected in ongoing erosion cycles, especially at its edges, but also within itself. It is these processes that trigger the ever-changing composition of vegetation communities in the ecoregion and have implications for the conservation of biodiversity, especially in the face of climate change.

Early hominids in Africa used fire at least 1.5 million years ago (Goldammer 1991) and have ever since acted as a dominant ecological factor influencing vegetation. The earliest positive evidence of the use of fire by man in central Africa is dated more than 53,000 years ago (Clark 1959). It is also argued that during the 1800 years since the Iron Age man occupied the Miombo Ecoregion, vegetation changes have been brought about mainly through the burning and cultivating activities of man (West 1971).

Fires in the Miombo Ecoregion occur regularly and frequently and originate from people preparing land for cultivation, collecting honey or making charcoal. Some fires are set by hunters, either to drive animals or to attract them later to the grass re-growth areas that were burnt, and by livestock herders to provide a green flush for their livestock and to control pests, such as ticks. Generally, people use fire to clear areas alongside paths connecting rural settlements. Such practices have probably been carried out for millennia. The fires occur throughout the dry season but most occur from July to October (Chidumayo 1997) and are fuelled largely by grass and woody plant leaf litter. Fire intensity is therefore linked to grass production in the previous rainy season, intensity of grazing and extent of woody plant cover. Fires tend to be more frequent and intense in areas of low woodland cover, medium to high annual rainfall, low grazing and low to medium human population density.

Palaeo-fire regimes have varied with the influence of climate and man. It is difficult therefore to draw a general prehistoric fire regime in the Miombo Ecoregion. Even the present-day fire regime is difficult to define from objective data because direct field observations are too scarce and scattered, while satellite determination of fire and burned areas is still not able to give a good regional view of the phenomenon throughout the year (Delmas *et al.* 1991). At local scale fire return periods range from 1 to 2 years, but at regional scale this is estimated at 3 years (Frost 1996).

The impact of fire on vegetation depends on the intensity and timing in relation to plant phenology. Intensity varies with time of burning and amount of fuel. Late dry-season (August–November) fires are more intense and destructive than fires in the early dry season (April–July) when much of the vegetation is green and moist. Usually fire intensities in the late dry season are

5–18 times those observed for early dry season fires (Frost 1996). Late dry season fires are also more destructive because they occur when trees have flushed.

Response to fire is variable among tree species. The extremes of the response continuum are defined by intolerant species that cannot survive fire, and are therefore are restricted to fire protected areas, and fire-tolerant species that survive regular intense fires. The trees of evergreen forests (e.g. *Cryptosepalum*, swamp and riparian forests), are nearly all highly intolerant of and easily damaged by fire, but trees in frequently burnt savanna vegetation in medium to high rainfall areas, including *Brachystegia* and *Julbernardia* species, are all fire tolerant. However, it is also true that all trees and shrubs will eventually be eliminated from savanna vegetation if the fires are sufficiently intense, and repeated during the late dry season over a sufficient number of years (West 1971). Under such conditions, the woody plants that persist are only those species which survive fire by underground tissues, from which they are able to re-sprout after fire during the next growing season. Grassland, in areas where edaphic conditions permit tree growth, is the ultimate product of fire because it is composed of plants most tolerant of fire. These plants are characterised by aerial parts that die off seasonally in the dry season and/or have dormant buds that are protected from fire damage by soil (geophytes and hemicryptophytes), or dead tissues just above the soil surface (chamaephytes) such as leaf bases or bulbs. Thus fire can cause changes in species composition and structure of vegetation. Frequent late dry-season fires eventually transform forest or woodland into open, tall grass savanna, with only isolated, fire-tolerant canopy trees and scattered smaller trees and shrubs (e.g. chipya vegetation). In contrast, woody plants are favoured by both early burning and complete fire protection. Fire therefore is one of the key ecological factors in Miombo Ecoregion and its management has considerable implications for biodiversity conservation.

3. BIOLOGICAL FEATURES AND SPECIES

3.1 Ecoregion Boundary

The revised Miombo Ecoregion, also termed the Southern Caesalpinoid woodlands, is an amalgamation of a number of the smaller ecoregions shown on the WWF-US Conservation Science Programme map "Terrestrial Ecoregions of Africa" (WWF 1999). It is a broad, heterogeneous region that covers a large part of south-central Africa, but with many internal similarities and links. In many respects the revised Miombo Ecoregion can be considered a "super ecoregion" or biome.

This super-ecoregion is a broader unit than true miombo woodland (defined as woodland dominated by trees of the genera *Brachystegia*, *Julbernardia* and *Isoberlinia* with a well-developed grass layer), and is defined by the dominance (or high frequency) of trees belonging to the legume sub-family Caesalpinioideae, such as *Brachystegia*, *Julbernardia*, *Isoberlinia*, *Baikiaea*, *Cryptosepalum*, *Colophospermum* and *Burkea*. Its distribution and subdivisions are shown in Figure 4.

White's original vegetation map (White 1983) was used as a basis for the revision, modified using a number of national and regional studies[1]. The final map closely follows the boundaries of the White's Zambezian Regional Centre of Endemism, except for the transition to the Guinea-Congolia and Zanzibar-Inhambane phytochoria. It also broadly corresponds to the broad-leaved dystrophic savanna woodlands of southern Africa (Huntley 1982).

The revised Miombo Ecoregion extends from the upper edge of the Angolan escarpment in the west to the beginnings of the coastal woodlands and forests of Mozambique and Tanzania in the east (Southern Zanzibar–Inhambane coastal forest mosaic of Burgess *et al.* 2004), although it does not include those types. To the west and southwest it is bounded by Kalahari *Acacia* woodlands in Namibia and Botswana (Kalahari *Acacia–Baikiaea* Woodlands of WWF, in part), and to the south by Highveld grassland and mixed *Acacia* woodland in South Africa (Highveld Grasslands of WWF). To the north it grades into Guinea-Congolian moist evergreen forest of the Congo Basin (Southern Congolian Forest–Savanna Mosaic of WWF), while in the north-east it is bounded by dry *Acacia-Commiphora* bushland in Tanzania (Southern *Acacia–Commiphora* Bushlands and Thickets of WWF). Nomenclature of the revised units is quite different from that of the original WWF map, and in many cases the units are substantially different. A comparison with the WWF-US Ecoregion map is given in Table 1. The total area of the Miombo ecoregion (excluding water bodies and mountains) is 3,649,568 km^2.

3.1.1 Inclusions and Exclusions

Although within the geographical extent of the southern Caesalpinoid woodlands, Afromontane forests and grassland (units 76, 77, 78, 80 (part) of WWF) are <u>excluded</u> from the biological and other descriptions of the ecoregion. Their ecology and species composition are very different. Also excluded are large water bodies such as lakes Kariba, Malawi and Tanganyika have been excluded.

[1] National and regional studies used were: Acocks 1975, Barbosa 1970, Bekker & de Wit 1991, Giess 1971, C. Hines (pers. comm. 2002), Low & Rebelo 1998, Mendelsohn & Roberts 1997, Mendelsohn *et al.* 2000, Pedro & Barbosa 1955, Timberlake *et al.* 1993, Timberlake *et al.* 1994, Wild & Barbosa 1967.

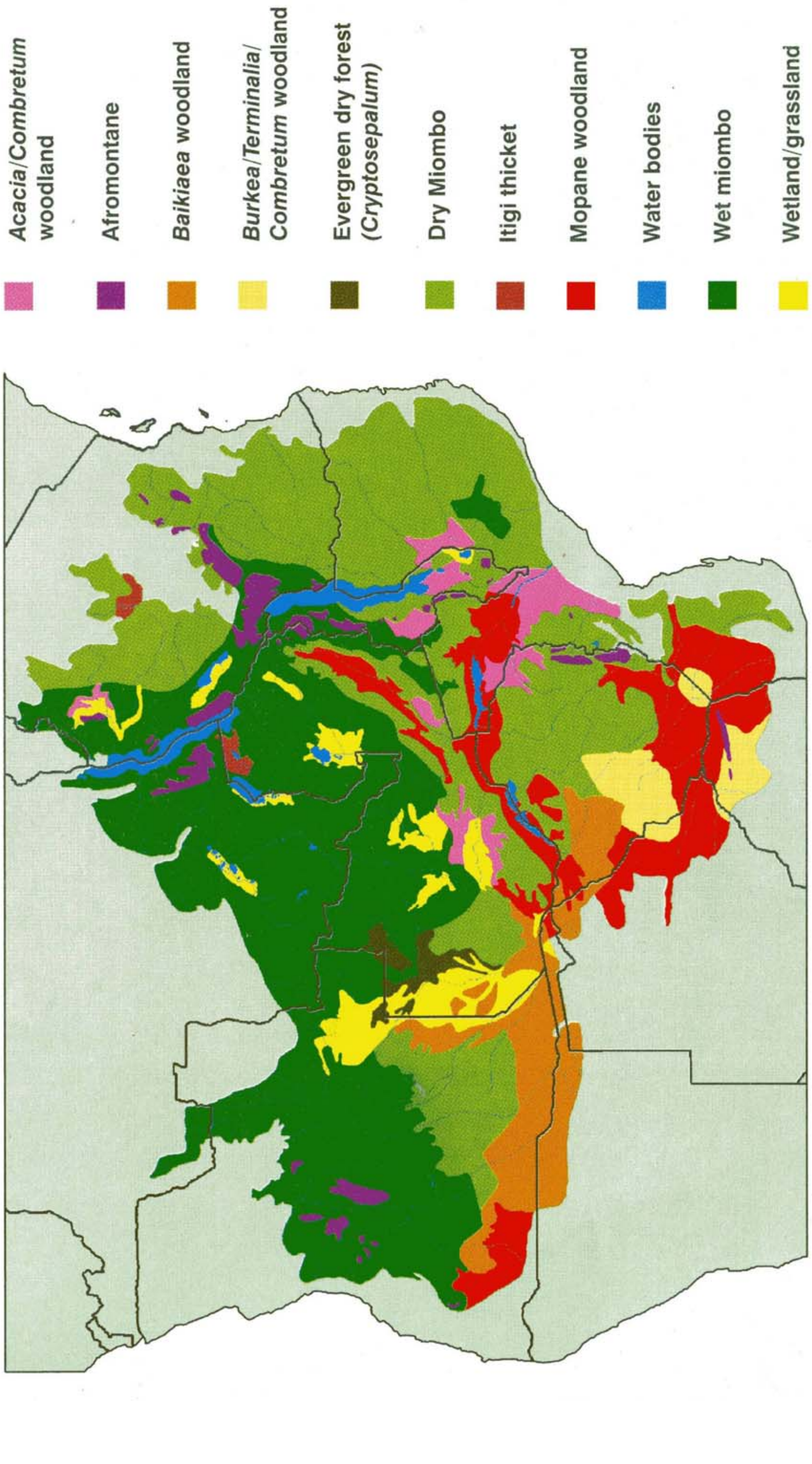

Figure 4. Miombo Ecoregion – vegetation types (from WWF SARPO 2003).

Edaphic grasslands, floodplains, dambos and wetlands are, however, included within the revised ecoregion. They are considered to be an integral part of the woodland landscape and ecological processes, and functionally are not separable.

Table 1. Revised Miombo Ecoregion vegetation units.[2]

Vegetation unit	**WWF (1999) unit**	**area (km^2)**
Itigi thicket	48	15,405
Cryptosepalum dry forest	32	37,908
Wet miombo woodland	49 (most), 50	1,358,175
Dry miombo woodland	52, 53	1,214,533
Burkea–Terminalia woodland	57 (part)	96,162
Mopane woodland	54 (part), 55 (part)	384,037
Baikiaea woodland	51, 58 (part)	260,171
Acacia–Combretum woodland	54 (part)	103,887
Wetland grasslands	56 (part), 63	179,290
Other areas (not part of ecoregion), e.g. water bodies, mountains		167,636
TOTAL		3,817,204

3.2 Vegetation Types

The two characteristic features of the Southern Caesalpinoid Woodland Ecoregion are the presence of woodland dominated by trees from the legume subfamily Caesalpinioideae, such as *Brachystegia*, *Julbernardia*, *Isoberlinia*, *Baikiaea*, *Cryptosepalum*, *Colophospermum* and *Burkea*, and the presence of a well-developed grass layer composed of C4 grasses. Caesalpinoid woodlands are composed of pinnate broad-leaved tree species, most being deciduous for at least a short period each year, the seasonality being related to a period of water stress and/or low temperatures. The woodland canopy is from 6 to 20 m in height, and ranges from 20% cover to almost closed-canopy forest.

Caesalpinoid woodlands are mostly found on nutrient-poor soils (except *Colophospermum* and *Acacia–Combretum* woodland). Vegetation composition and structure are determined by climate (rainfall amount, length of dry season, mean temperature, frost), position in the landscape and soil type. Most changes in vegetation type within the ecoregion are gradual. Fire is an important feature.

Another characteristic feature is the presence of large termite mounds, especially where sub-soil drainage is impeded. These are composed of cation-rich (particularly calcium) soils owing to their high clay contents, and generally have lower soil moisture levels. Termitaria support very different species from the surrounding woodlands. Their presence, as nutrient-enriched 'islands', is of major significance for both species diversity and woodland ecology.

[2] Areas taken from version of original hand-drawn map of Timberlake, digitized by WWF SARPO GIS Unit in 2001.

The main genera of Caesalpinoid trees have explosively-dehiscent pods and seeds that are not distributed far. Genera dominant in wet and dry miombo vegetation are mostly ectomycorrhizal (they have symbiotic fungi associated with the root cortex), a feature often associated with impoverished phosphorous-deficient soils (Högberg 1986, Högberg & Piearce 1986) and forest trees, while the genera dominant in *Baikiaea*, *Burkea–Terminalia*, mopane and *Acacia–Combretum* woodlands are all endomycorrhizal (fungal hyphae penetrate the root cells), which is much more common in the tropics.

Caesalpinoid woodlands are tolerant of significant damage from drought, fire, frost and megaherbivore browsing, as most of the major trees can readily coppice. This distinguishes them from moist forests and from *Acacia* savannas which reproduce and recover more readily from seed.

The ecoregion is divided into nine major vegetation or habitat types, each with a distinctive ecology and species composition.

Itigi-like thicket: Dry deciduous forests are found in the north east (the Itigi thickets of Tanzania and Zambia), dominated by *Baphia* and *Combretum* species and *Bussea massaiensis*. Further south, in the Zambezi and Shire valleys, there are similar thickets characterised by early-deciduous *Combretum* shrubs and scattered emergent deciduous or evergreen trees. In places *Xylia torreana* forms a canopy. Many of these thicket patches are too small to map at the present scale. They are of significant conservation interest owing to their limited extent.

***Cryptosepalum* dry forest**: Dry evergreen forest dominated by *Cryptosepalum exfoliatum* is found on Kalahari sands associated with the upper Zambezi in western Zambia. Other typical species include *Parinari excelsa* and *Marquesia* species, often with lianas. Although the forest is evergreen, the type is clearly distinct from the moist forests of the Congo Basin. Annual rainfall is around 900 mm.

Wet miombo woodland: A species-rich woodland with a canopy usually greater than 15 m high. Dominant species include *Brachystegia floribunda*, *B. glaberrima*, *B. taxifolia*, *B. wangermeeana* and *Marquesia macroura*. Annual rainfall is reliable and usually more than 1000 mm, but less in areas on Kalahari sands. The herbaceous layer comprises tall grasses such as *Hyparrhenia*. In the wettest areas the dominant trees are only briefly deciduous, the canopy is almost closed, and shade-tolerant species (e.g. from the family Rubiaceae) are found in the understorey. A number of floodplains and swamp grasslands are found along major rivers such as the Zambezi, Kafue, Chambeshi and Kilombero, as well as extensive dambos on the gently undulating plateau.

Within wet miombo there are inclusions of "chipya", an open non-miombo formation with very tall grass and a high complement of evergreen species. This is thought to have been derived from forest patches through fire, and is found on richer soils.

Dry miombo woodland: This type is floristically poorer than wet miombo with *Brachystegia spiciformis*, *B. boehmii* and *Julbernardia globiflora* dominant; *B. floribunda* is generally absent. The canopy is generally less than 15 m in height and trees are deciduous for a month or more during the dry season. Species of *Acacia* are found on clay soils in drainage lines. Annual rainfall is less than 1000 mm and less reliable than further north. The herbaceous layer consists of medium to tall C4 grasses. In drier areas, *Julbernardia* and *Combretum* become dominant. There is an extensive area on Kalahari sands in central Angola dominated by thicket-forming *Brachystegia bakeriana*, which appears transitional to *Baikiaea* woodland.

As dry miombo woodland is found on escarpments as well as on the plateau and coastal plain, the geomorphology and soils are more varied than with wet miombo. There is also a significant inclusion of mopane, *Acacia* and *Combretum* woodlands in places. There are no significant areas of floodplain grassland or wetlands, but seasonally waterlogged drainage-line grasslands (dambos) are common on the central plateau.

***Burkea–Terminalia* woodland**: This rather impoverished woodland type is found at the southern margins of the ecoregion. Although similar in structure and broad ecology to dry miombo woodland, it does not contain any of its defining species. Instead there is a high frequency of *Burkea africana*, *Terminalia sericea*, *Combretum*, *Pterocarpus*, *Pseudolachnostylis maprouneifolia* and other broad-leaved trees typical of dystrophic woodland, along with species of *Acacia*, *Albizia* and *Peltophorum africanum*. There are many rocky outcrops which support mesic species.

It is principally found on the southern part of the central plateau at over 1000 m altitude. Annual rainfall is around 600 mm, with high variability. The type has been much modified by human activity.

***Baikiaea* woodland**: *Baikiaea* woodland varies in structure from almost dry forest or thicket to a moderately-dense woodland. It is characterised by a dominance of the deep-rooted tree *Baikiaea plurijuga*, and is confined to deeper Kalahari sands. Canopy height varies from 8 to 20 m, depending on rainfall. Other typical species include *Burkea africana*, *Combretum collinum* and *Guibourtia coleosperma*. The type is deciduous, often for some months. Annual rainfall varies from 500 to 800 mm, but the deep sands absorb and retain moisture well so deep-rooted trees retain their leaves for an extended period.

Mopane woodland: Mopane woodland is characterised by the dominance of *Colophospermum mopane* with a canopy from 6 to 18 m high, depending on rainfall and soil depth. Trees are deciduous for some months of the year. The grass layer is generally poorly developed. These woodlands are species-poor; associated species include *Acacia* and those from the Capparidaceae family.

It is associated with nutrient-rich clay soils of the wide, flat valleys such as the Limpopo, Save, Zambezi, Luangwa and Cunene. Altitude ranges from 300 to 900 m. Mopane woodland is a eutrophic (nutrient-rich) type with a different ecology to true miombo. Annual rainfall is around 400 to 700 mm with high variability, but soil infiltration rates are low.

***Acacia–Combretum* woodland**: This type comprises open woodland to wooded grassland dominated by species of *Acacia* and *Combretum*, often with trees from the legume subfamily Papilionoideae. There are two variants. One is found up on the central plateau of eastern Zambia in dry miombo on areas of nutrient-rich soil, sometimes locally called "munga". It consists of open woodland to wooded grassland with a well-developed grass layer, and is frequently burnt. Along with *Combretum* and *Terminalia*, a number of mesic *Acacia* and *Albizia* species, and species from the families Papilionoideae and Bignoniaceae occur. The other variant is found where the central plateau falls away to the Mozambique coastal plain and Zambezi valley. The climate is generally warmer, and fire is less frequent. *Acacia nigrescens* and *Combretum* species are very common, and are associated with *Lonchocarpus capassa*, *Xeroderris stuhlmannii*, *Sterculia africana*, *Adansonia digitata* and *Cordyla africana*. Mopane is often present, but is not dominant or abundant. The grass layer is variously well or poorly-developed, depending on soil depth and rainfall.

Wetland grassland: Edaphic grasslands, floodplains, dambos (seasonally waterlogged drainage grasslands) and wetlands are of sizeable extent in Zambia (Barotse floodplains, Kafue Flats, Busanga and Lukango and Bangweulu swamps), Tanzania (Lake Rukwa, Mavowsi/Igombe, Kilombero valley) and Malawi (Lake Chilwa). Wetland vegetation is often dominated by stands of papyrus (*Cyperus papyrus*) or reed (*Phragmites mauritianus*/*P. australis*) with floating-leaved aquatics. Floodplains are extensive areas flanking rivers that are occasionally flooded. They are usually more species-rich than wetlands, but are dominated by grasses and sedges. In seasonally-inundated areas, similar edaphic grasslands can be found, with a rich geophyte flora. Dambo vegetation consists of open grasslands with scattered trees, often rich in forbs and suffrutex woody plants.

3.3 Species

3.3.1 Plants

The ecoregion contains around 8,500 plant species, of which about 54% are endemic (White 1983). There are no endemic families. The Zambezian Regional Centre of Endemism (equivalent to the Miombo Ecoregion) probably has the richest and most diversified flora and the widest range of vegetation types in Africa (White 1983). It is the centre of diversity of both *Brachystegia* and *Monotes*, and also for geoxylic suffrutex species ("underground trees"), an unusual life form. Of 98 geoxylic suffrutex species listed for Africa, 86 are recorded only from this area (White 1976).

The genera *Bolusanthus*, *Cleistochlamys*, *Colophospermum*, *Diplorhynchus*, *Pseudolachnostylis* and *Viridivia* are endemic, while *Androstachys* and *Xanthocercis* otherwise only occur in Madagascar. In addition to the characteristic Caesalpinoid trees, species of *Acacia*, *Combretum*, *Erythrophleum*, *Monotes*, *Parinari* and *Terminalia* are typical of these woodlands. The Great Dyke in Zimbabwe (20–30 species), Katanga (Haut-Shaba) in the DRC (56 species), the Itigi thickets in central Tanzania/NE Zambia (5–10 species?), and the high plateau around Huambo in central Angola (between 200–500 species) are particularly rich in endemic species.

Around 100 threatened species are thought to occur in the ecoregion, of which nine are Endangered or Vulnerable. There are 39 threatened tree species, of which 19 are Endangered or Vulnerable (Walter & Gillett 1998, Oldfield *et al.* 1998). Plant Red Data lists for a number of countries in the region are under preparation through the SABONET project.

Major timber species are *Baikiaea plurijuga*, *Guibourtia coleosperma*, *Pterocarpus angolensis*, *Afzelia quanzensis*, *Millettia stuhlmannii* and *Dalbergia melanoxylon*. A number of trees are widely used for construction timber or firewood, including *Brachystegia*, *Terminalia* and *Acacia* species, *Pericopsis angolensis* and *Colophospermum mopane*. The tree *Warburgia salutaris* is severely threatened from over-harvesting for medicinal use. Various wetland plants are of economic significance including *Phragmites* and *Cyperus papyrus*, while important water weeds are *Azolla*, *Eichhornia*, *Pistia* and *Salvinia*. Many grasses are of great importance for grazing to livestock and wildlife, including species of *Brachiaria*, *Digitaria*, *Eragrostis*, *Heteropogon*, *Hyparrhenia* and *Panicum*.

3.3.2 Mammals

Perhaps the most conspicuous and charismatic feature of the ecoregion is the wide variety and large numbers of large mammalian herbivores (elephant, white and black rhino, hippo, giraffe, zebra, buffalo and numerous antelope) and large predators (lion, cheetah, leopard, hyaena, wild dog). Primates are represented by chimpanzee (on the ecoregion margins), baboon, bushbabies and several species of diurnal monkey. The variety of monkeys is greater in the north where the ecoregion grades into forest ecosystems. The distribution and status of the smaller mammals in the area – rodents, bats and insectivores – is still poorly known.

Species richness of antelopes reflects the diversity of habitats, which include wetlands with specialised species such as lechwe *Kobus leche* (*sensu lato*, including the Kafue lechwe *K. kafuensis* and black lechwe *K. smithemannii*) and puku *Kobus vardoni*. There are believed to be a number of extant or extinct taxa of lechwe (perhaps 8 to 10), indicating fragmentation of wetland grassland over the last million years (Cotterill 2000). Other groups of antelope also show signs of speciation across the extent of the ecoregion, for example: defassa waterbuck *Kobus ellipsiprymnus defassa* in the north and west and *K. e. ellipsiprymnus* in the south and west; brindled wildebeest *Connochaetus taurinus taurinus* south of the Zambezi, Nyassa wildebeest *C. t. johnstonii* in northern Mozambique and southern Tanzania and the endemic Cookson's wildebeest *C. t. cooksoni* in the Luangwa valley (E. Zambia); Masai giraffe *Giraffa cameleopardus tippelskichi* in southern Tanzania, Thornicroft's giraffe *G. c. thornicrofti* in the Luangwa valley and the southern giraffe *G. c. giraffa* in southern Zimbabwe; and the southern reedbuck *Redunca arundinum* and Bohar reedbuck *R. redunca* whose distribution ranges overlap in the Selous Game Reserve in southern Tanzania.

Lichtenstein's hartebeest *Alcelaphus lichtensteinii* and sable antelope *Hippotragus niger* are largely confined to *Brachystegia/Julbernardia* woodland and can be said to be near-endemic to the ecoregion. The threatened giant sable *H. n. variani* is restricted to a small part of central Angola. Sharpe's grysbok *Raphicerus sharpei* and the miombo genet *Genetta angolensis* are also near-endemics. Among small mammals there are a few rodents and bats known only from the ecoregion or small areas within it. Appendix 1 gives an indication of the species confined (or nearly confined) to the Miombo Ecoregion.

Only one taxon, Robert's lechwe *Kobus leche robertsii* is known to have become extinct within the ecoregion within the last 500 years. However, four mammals are Critically Endangered – black rhinoceros *Diceros bicornis*, giant sable antelope, a white-toothed shrew *Crocidura ansellorum* and a climbing mouse *Dendromus vernayi*. The black rhino formerly occurred throughout the area, but has been greatly reduced in number and range. The ecoregion contains about 620 animals, 23% of the continental population, and around 2900–3000 white rhino *Ceratotherium simum*, or 29% of the continental population. Endangered species include the African elephant *Loxodonta africana* and wild dog *Lycaon pictus*. Southern Tanzania. Malawi, Mozambique, Zambia and Zimbabwe contain at least 128,000 elephant, representing 42–45% of Africa's population. The same area contains most of Africa's remaining wild dogs.

Nine areas of importance for mammals have been identified. These are: Liuwa plains (W Zambia; animal movement); Mwinilunga/Solwezi (NW Zambia; small mammal endemism); Hwange-Chobe-Caprivi (NW Zimbabwe/N Botswana; large mammal assemblage); Bangweulu/Kasanka (N Zambia; large mammal assemblage, endemism); Luangwa Valley (E Zambia; large mammal assemblage, elephant, endemism); mid-Zambezi valley (N Zimbabwe; large mammal assemblage, elephant, hippo); Niassa/Selous (N Mozambique/S Tanzania; large mammal assemblage); Gorongosa–Cheringoma–Zambezi delta (C Mozambique; large mammal diversity); and Gaza–Kruger–Gonarezhou (SE Zimbabwe/N South Africa; large mammal assemblage, small mammal endemism).

The species richness and locally high biomass of large mammals forms the backbone of the region's tourism industry. Wildlife-viewing and safari hunting for trophies are two major forms of wildlife use. Elephants are the most financially valuable species. Increasingly within the region, local communities are able to receive proceeds from tourism, so wildlife has become a major form of land use in places. Elephants, lions, baboons and other animals can also have a significant negative impact when they destroy crops or kill people and livestock During recent decades, both the elephant and black rhino were of economic importance, albeit illegally, through killing for their ivory and horn. Many antelope are hunted widely (legally or illegally) for their meat and skins, both by local peasants and land owners.

3.3.3 Birds

There is no full list of bird species from the ecoregion; most studies have been national. However, 938 species of passerines (including subspecies) are indicated for the region. Bird atlases for Zimbabwe, Botswana and part of southern Mozambique are available, while atlases of Zambia, Malawi, Tanzania and central Mozambique are in preparation. A number of areas, including many national parks, have more than 400 recorded species, but this is an effect of high observer coverage.

About 51 bird species are restricted to the Miombo Ecoregion or Zambesian biome (P. Frost, pers. comm.), including 23 species endemic to *Brachystegia* woodland (Barnes 1998, Fishpool 2001, Benson & Irwin 1966, P. Frost pers. comm. 2001); 23 others are near-endemic. These are listed in Appendix 1. Other species are confined to grasslands of the palaeo-Upper Zambezi system. Bird species diversity is higher towards the Angolan highlands in the west and Tanzania in the north east. In part this is due to the greater diversity in montane 'islands' within the ecoregion. Wetlands are particularly important for bird life, especially for palaearctic and intra-African migrants.

There are around 80 Important Bird Areas within the ecoregion, containing significant numbers of globally or nationally threatened species (Fishpool 2001). Significant areas include Bangweulu swamps (Shoebill Stork, Long-tailed Flufftail and high numbers of waterbirds), Angolan escarpment (five threatened species, although mostly forest not woodland species), Matobo Hills (high diversity and breeding density of raptors, especially Black Eagle), and the Kafue Flats (high waterfowl numbers, 79 waterbird species).

Threatened species include the Wattled Crane *Bugeranus carunculatus*; the area contains about 90% of the world population of 13,000–15,000 birds. The White-winged Flufftail *Sarothrura ayresi* is Endangered. Species listed as Vulnerable are the Lappet-faced Vulture, Cape Griffon, Slaty Egret and the non-breeding migrants Lesser Kestrel, Madagascar Pond Heron, Corncrake and Spotted Eagle.

The Ostrich *Struthio camelus* is farmed for its skin and meat, and the Red-billed Quelea *Quelea quelea* is a major pest to grain farmers in some places.

3.3.4 Reptiles / Amphibians

There are 284 species of reptile and 130 amphibians recorded from the ecoregion, with 52 and 25 endemic species respectively. The largest reptile is the Nile Crocodile, which is numerous in low-altitude perennial rivers. It is also the basis of a commercial industry.

Ten areas of high reptile/amphibian diversity have been identified. The highest diversity is found in Upemba National Park in the DRC (100 reptiles and 50 amphibians), Shashe in SW Zimbabwe/N South Africa (100 reptiles and 18 amphibians), including species more typical of the Kalahari, and the Hwange National Park area (81 reptile and 25 amphibian species).

Seven areas of endemism have been identified of which the richest are Upemba /Kandelungu National Parks (7 reptile and 6 amphibians), the Rovuma area of SE Tanzania-NE Mozambique (11 reptile and 4 amphibians), and Barotseland (5 reptiles and 2 frogs).

The major threatened reptiles are the Slender-snouted Crocodile *Crocodylus cataphractus* in Lake Mweru and the Flap-shell Turtle *Cycloderma frenatum*. However, a proper assessment of threat for reptiles and amphibians has still not been completed and there are likely to be more

3.3.5 Fish

The Zambezian ichthyological province, which includes the Zambezi basin and rivers that were once part of it (e.g. the Cunene), contains 196 fish species. This total excludes Lake Malawi with 600–800 species. Around 25 species have been introduced into the area over the last 100 years, but most have failed to establish.

Excluding the Great Lakes with their exceptional species richness, there are two areas of particular fish species richness within the ecoregion — Lake Mweru and the Luapula River with 94 species, and the Upper Zambezi with about 92 species (B. Marshall, pers. comm.).

Fifteen species are endemic to the palaeo-Zambezi basin, including four endemics in the Chambeshi River and Lake Bangweulu, with an additional 15 species being near-endemic (Marshall 2000, B. Marshall pers. comm.). There are four major areas of endemism – Lake Malawi (600–800 species, of which 99% are endemic), Lake Tanganyika (290 species, of which 90% are endemic), the Lake Malawi drainage basin (38 species, of which 25% are endemic) and the Cunene River (63 species, of which 13% are endemic).

A number of species from the Congo system are only known from very few specimens. This may be an artefact of lack of collecting. Six species are under threat: *Opsaridium peringueyi* (semi-arid Save and Limpopo systems); *Nothobranchius furzeri* (a few pans in southeastern Zimbabwe); *Chiloglanis emarginatus* (South Africa, 2 specimens in Zimbabwe);*Oreochromis mossambicus* (widespread in the lower Zambezi, but are under threat from the exotic *O. niloticus*); *Oreochromis andersonii* and *O. macrochir* (similar threat); and *Nothobranchius* sp. (small pans in the Caprivi Strip).

Fish are of major economic significance as a source of protein, particularly around the larger water bodies. Sport-fishing for tigerfish *Hydrocynus vittatus* has important economic benefits around Lake Kariba and in some parts of the Zambezi.

3.3.6 Invertebrates

Invertebrates in the region are poorly known. The best-known groups are: Lepidoptera (butterflies, emperor moths, hawk moths), Diptera (tsetse flies, mosquitoes), Coleoptera (dung beetles, flower chaffers), Orthoptera (grasshoppers/locust, mantids), Isoptera (termites), Mollusca (freshwater species) and agricultural pests and invertebrates of medical and veterinary importance (ticks, helminths).

There are 102 recorded species of freshwater mollusc (gastropods and bivalves) within the Zambezi basin, which is not diverse by African standards, including 23 endemics. Lake Malawi contains 52% of these (19 endemic), but Lake Tanganyika is considered richer (Dudley 2000). The Congo basin (including the Luapula) is considered to be more diverse. Upemba National Park, perhaps the best-collected area, contains 70 species of terrestrial mollusc, of which 22 have not yet been recorded elsewhere (van Bruggen & van Goethem 2001). Land snails have 650 species in southern Africa as a whole, with about 90% endemic. However, over half of all recorded species are from forests, which are not included in the ecoregion.

Termites are an important group in the Caesalpinoid woodlands, not just in assisting decomposition of organic matter, but also in the effect their mounds have on spatial distribution of nutrients, plants and animals. They are of major economic significance for their ecological value. Southern Africa is known to be rich in termite species, however there appears to be little data on either their diversity or distribution across the ecoregion. Malawi has 106 species.

Table 2. Numbers of species recorded from the Miombo Ecoregion.

Group	**no. species in ecoregion** [1]	**no. endemic/ near endemic species**
Plants [3]	8500	4590
Mammals [2]	318	35
Birds [4]	938	51
Reptiles [5]	284	83
Amphibians [5]	130	36
Fish [6]	±200	30
Butterflies [7]	±1300	90
Total	11,670	4915

Sources: Regional specialists (D. Broadley, F. Cotterill, P. Frost, A. Gardiner, B. Marshall, P. Mundy); WWF Conservation Science Division ecoregion database, Oct. 2001 (data compiled from original WWF Ecoregions delineation, not the revised version presented here).

Notes: 1. Numbers reflect species, not sub-taxa, a number of which should be raised to full species.
2. Mammal species data from WWF-US terrestrial vertebrate database, Oct 2001; endemism from F. Cotterill (Nov 2001).
3. Plant data from White (1983).
4. Bird data from P. Mundy (Nov 2001) and P. Frost (Dec 2001).
5. Herps data from D. Broadley (Nov 2001).
6. Fish data from B. Marshall (Nov 2001); excludes species from the Great Lakes.
7. Butterfly data from A. Gardiner (Jan 2002).

Odonata are a comparatively well-known group. The Zambezi basin wetlands (including the headwaters) have 217 species (Fitzpatrick 2000), of which 148 are found in the headwaters (12 apparently endemic). The Katombora/Victoria falls area downstream has 88 species (1 endemic).

Lepidoptera (particularly butterflies) are better known. There are 588 species recorded from along the Zambezi River, with the highest diversity in the headwaters (467 species), compared to only 181 in the Chobe–Victoria Falls area. It is estimated that the Miombo Ecoregion contains 1300 butterfly species, of which around 90 are endemic (Gardiner 2000). As is the case in many invertebrate groups, it is the wetter miombo woodland and forest mosaics of northwest Zambia, northeast Angola and the DRC that have the greatest diversity and endemism. Some moth species are of economic significance for their caterpillars, for example the mopane worm *Imbrasia belina* and many species in Katanga (Shaba).

Six areas of importance for invertebrates have been provisionally identified from within the ecoregion: Mwinilunga–Mkushi (NW Zambia; species diversity (butterflies 66, 1 endemic), endemism); Kazungula (NW Zimbabwe, Odonata diversity); Eastern Highveld (E Zimbabwe; butterfly diversity (300), endemism (3 butterflies)); the Luapula River (NE Zambia; freshwater molluscs); Sumbananga–Kigoma (E Lake Tanganyika; butterfly diversity (500), endemism); and Madidibira–Mafindi (S Tanzania; butterfly diversity (400), endemism (5 butterflies)).

3.4 Areas of Evolutionary Significance

Various parts of the Miombo Ecoregion have been important in the past both for local vicariant evolution and for radiation of specific groups. The Great Dyke in Zimbabwe and the Kolwezi-Lubumbashi area of the DRC/N Zambia (Wild 1965, Brooks & Malaisse 1985) with serpentine soils have given rise to the evolution of many endemic plants adapted to mineral-toxic soils (20–30 and 53 species respectively), while the isolation of Lake Malawi and Lake Tanganyika has given rise to great diversification of freshwater fish and molluscs (Marshall 2000, Dudley 2000). There are 600–800 fish species in Lake Malawi (99% endemic) and 240 species in Lake Tanganyika (90% endemic). These fish species flocks have evolved in the past 1–2 million years and there is a very high degree of local variation indicating that speciation is still continuing.

The grasslands, floodplains and wetlands of the palaeo-Upper Zambezi (Barotseland, Kafue, Bangweulu, etc.) are believed to have been closely connected during past wetter periods, and to have covered a vast area in the north. For many biological groups, this landscape of grassland and woodland patches on Kalahari sands appears to have been an important centre of diversification and speciation over the last 5 million years, including for lechwe and similar antelope, suffrutex plants and grassland birds (Cotterill 2000, Timberlake *et al.* 2000, Mundy 2000). Much of the speciation was caused by habitat fragmentation owing to climatic change, and the capture of the Upper Zambezi by what is now the middle and lower Zambezi. Barotseland is regarded as a particularly rich area for reptiles and amphibians as it is the meeting place of the Kalahari, forest and savanna faunas.

The Muchinga escarpment in eastern Zambia has been a biogeographical boundary resulting in speciation in primates (*Papio* and *Cercopithecus*), waterbuck, tsessebe and puku. The watershed between the Chambeshi, Upper Luangwa and Rukwa has had a similar effect, separating southern and East African taxa.

3.5 Areas Important for Animal Movement and Migration

Seasonal movement of vertebrates such as birds and large mammals is a characteristic feature of parts of the Miombo Ecoregion. Many movements are related to feeding, and are driven by the availability of food in nutrient-rich or warmer parts of the landscape (wetlands, mopane woodland, riverine woodland) compared to deficiency in nutrient-poor areas up on the plateau or cool areas with little insect activity. However, most of these movements do not follow a fixed pattern and are rather opportunistic and over only moderate distances. Examples are elephants moving across northern Botswana and western Zimbabwe, and from the Zambezi floodplains up onto the escarpment. The only true migration of large mammals is thought to be of wildebeest from the Liuwa Plains in western Zambia into eastern Angola.

Within a landscape, there is often a vegetation catena related to topography. The catena can be divided into run-off areas, consisting of raised interfluves, and run-on areas consisting of dambos (wet grasslands). Dambos often act as a magnet for wildlife during the dry season. For example, after the end of the rains antelope in the Zambezi valley move from vegetation types on dry soils such as mopane woodland when plant production ceases, to vegetation types on soils that remain moist well into the dry season. Riverine woodland and valleys on the plateau are also important movement corridors for a wide range of bird species.

Intercontinental migrations of palaearctic (100 species) and intra-Africa migrant birds (80 species) are common. The seasonal migrations of Palaearctic migrants enable them to breed in temperate Europe and Asia when food is seasonally abundant, and then move to southern Africa for the months when food availability is restricted in their breeding areas. These migrants range in size from white storks *Ciconia ciconia* to willow warblers *Phylloscopus trochilus*. Many are waders and the wetland areas of the ecoregion are important to them. Some of the major wetlands in Africa lie in southern Africa, such as the large natural lakes of Tanganyika, Malawi, Chilwa, Bangweulu and Mweru, two major man-made lakes, Kariba and Cabora Bassa, and major rivers such as the Zambezi, Luangwa, Shire and Kafue. African waterfowl censuses have identified many wetlands of international importance: two in Botswana, two in Malawi, seven in Mozambique, 26 in Tanzania, five in Zambia and four in Zimbabwe. Palaearctic migrants are protected by the African–Eurasian migratory water bird agreement of the Convention of Migratory Species of Wild Animals.

4. ECOLOGICAL DETERMINANTS AND PROCESSES

4.1 Ecological Determinants

The major ecological determinants in the Miombo Ecoregion are climate, soil moisture, soil nutrients, herbivory, fire and human use. Ecosystem diversity in the Miombo Ecoregion has evolved from the interaction between geology and the subhumid climate with seasonal rainfall. This interaction has given rise to a generally flat topography and sluggish drainage. The hydrology is therefore characterised by a mosaic of dambos and seasonally flooded grasslands, especially in the headwaters of the major rivers. The ecoregion exhibits landscape heterogeneity both at large and small scale. Consequently, it has higher between-habitat (beta) diversity than within-habitat (alpha) diversity. This implies that conservation of biodiversity is better achieved by conserving landscapes than isolated habitats.

4.2 Biophysical Processes

Whereas the broader ecoregion boundaries are controlled by climatic factors, the internal spatial variability is controlled more by edaphic factors, including soil moisture, soil nutrients and soil texture. However, the shallow plateau soils with a lateritic zone imply rapid soil moisture saturation during the rainy season which can potentially generate much surface and subsurface run-off. In many parts of the ecoregion, the vegetation cover that allows rainwater to infiltrate and recharge deep soil water also regulates this soil-water relationship. Lateral tree roots occupy a large part of the soil volume in *Brachystegia* woodland, which in turn protects the soil and conducts subsurface lateral flow. Run-on areas also reduce erosion as they act as sediment sinks. Widespread clearing of woodland cover on run-off areas can therefore disrupt the normal functioning of these hydrological processes through increased run-off, erosion and accelerated sedimentation of run-on areas with considerable impacts on wetland biodiversity. The understanding of these crucial linkages and feedback processes between physical and biological processes is important for conservation.

The linkage between seasonality in rainfall and primary production is well known in the Miombo Ecoregion. But landscape heterogeneity creates temporal and spatial differences in primary production, especially between run-off and run-on areas. For example, run-on areas, such as dambos, floodplains and swamps, sustain production even during the dry season, thereby freeing such areas from the constraint of rainfall seasonality. Hydrological processes that sustain this heterogeneity in soil moisture are themselves influenced by vegetation cover.

Seasonality in rainfall confines production by shallow-rooted plants to the rainy season, especially on run-off landscapes. However, deep-rooting plants, especially trees, have access to soil moisture stored at depth during most of the dry season. In this case, one of the key determinants of primary production is temperature. For example, *Brachystegia* woodland is deciduous for only a short period in the dry season, and may even be semi-evergreen in the wetter parts of the ecoregion. Annual growth often starts during spring (September) with the new colourful leaf flush, and stem expansion continues until May in the following year. Cessation of growth appears to be triggered by low temperatures ($<12^{o}$ C) during winter months, June to August (E. Chidumayo, unpublished). These winter low temperatures also retard primary production in wetland vegetation communities.

4.3 Plant Biomass and Herbivory

One of the emergent features of the Miombo Ecoregion that arises from the interaction of geomorphology and hydrology is the widespread occurrence of leached, nutrient-poor soils. Within this broad soil type, erosion and other physical processes have created soil nutrient gradients at different scales thereby creating a mosaic of dystrophic and eutrophic soils. A large part of the ecoregion covered with *Brachystegia* woodland, their associated broad-leaved *Burkea–Terminalia* and *Baikiaea* woodlands and *Cryptosepalum* forest, represents a low-nutrient ecosystem, deficient in protein but relatively rich in carbon. This has several implications for the functioning and state of ecological processes.

Because plant biomass has low levels of protein, mammal herbivory favours bulk feeders with a relatively long lifespan but a low reproductive rate (K-strategy species), such as elephant and buffalo (Byers 2001a). This in turn limits offtake by humans as secondary consumers. However, temporal and spatial variability in surface water and soil nutrients makes animal seasonal movements inevitable between the different habitats of the ecoregion. Valley or low-lying run-on areas covered with *Acacia* and mopane have eutrophic soils and plant production is more nutritious. Such habitats support more mammalian herbivores and higher biomass, especially during the dry season. However, some of the larger herbivores move out of such habitats into the adjacent nutrient-poor *Brachystegia* and *Burkea–Terminalia* woodlands, especially during the rainy season, to make use of the more nutritious green growth and abundant surface water. Again, these inter-habitat linkages emphasise the necessity of conserving biodiversity at a landscape rather than at a habitat scale.

4.4 Carbon Storage and Sequestration

Low herbivory and a high carbon content in plant biomass in the *Brachystegia* woodlands create opportunities for carbon storage. Much of the carbon in these woodlands is in the topsoil and woody biomass. Contrary to popular belief, soil organic matter in *Brachystegia* woodlands is not easily broken down, partly because of its structure and partly because of low soil moisture in the topsoil during the long dry season, which limits decomposer activity. Even after removal of vegetation cover, such soils do not show significant changes in organic matter content. For this reason, they can act as stable sinks for carbon.

Another characteristic feature of the ecoregion is the large number of wetlands that are rich in organic matter. These include the Bangweulu swamps, Mweru-Wantipa and the Kafue Flats. They serve as important carbon storage areas of regional and global significance and should be protected from land use activities that lead to the carbon release.

Woody biomass density declines along the rainfall gradient from north to south. Two types of *Brachystegia* woodlands are recognised: wet (>1000 mm mean annual rainfall) and dry (<1000 mm). Because of its higher density of woody biomass, wet miombo has greater capacity to store carbon than dry miombo. This presents opportunities for conserving areas of wet miombo for carbon storage. Such woodlands also cover most of the headwaters in the ecoregion and its conservation can serve the dual ecological functions of watershed protection and carbon storage, with significant regional and global benefits.

The majority of Caesalpinoid woodland species do not die after cutting but coppice readily. This implies that most of the root biomass is conserved after woodland clearing and does not decay to the extent of releasing most of the carbon contained in roots. And although these species grow slowly from seed because of the prolonged seedling phase lasting up to two decades or more, regrowth from coppice is faster because of the already established root system. It is conceivable therefore that regrowth woodland could be managed for carbon sequestration.

4.5 Nutrient Cycling

Low herbivory, high carbon content relative to nitrogen in plant biomass and a long dry season when topsoil moisture is deficient, have resulted into a slow nutrient cycling system within the ecoregion. Episodic outbreaks of insect herbivores, such as caterpillars and grasshoppers, may occasionally speed up nutrient cycling, but as a rule the region is characterised by very slow cycles. In fact, *Brachystegia* woodland trees show a high nutrient re-absorption rate (50–60%), especially of N and P, from leaves prior to leaf fall as a strategy for conserving these critical nutrients and reducing nutrient loss to other ecosystem components (Chidumayo 1997).

In some habitats, termites play an important role in nutrient cycling. They fall into three trophic groups: humus feeders, lignin feeders and mixed feeders. Humus feeders ingest decaying organic matter and mineral soil and produce a more stable organic matter in their faeces for the physico-chemical and bacterial agents of degradation. The lignin feeders, which include the large mound builders, attack intact vegetation and dead material under the cover of access routes. Some of these use the material to grow fungus in their mounds which produce termite mushrooms in the rainy season. Although lignin feeders are active throughout the year, peak activity occurs in the late rainy season. Other decomposers also show seasonal rhythms in their activity with most microbial processes reaching a peak during the rainy season. Leaf litter decomposition is rapid during the early rainy season due to the activity of bacteria, mites and Collembola.

Many woodland trees develop symbiotic relationships with fungi that live on or in their roots. These root fungi (mycorrhizae) have been reported to improve the nutrition, especially phosphorous absorption, and water uptake of the predominant tree species. Seedlings of *Brachystegia* and *Julbernardia* trees that normally take up to two decades or more before reaching the sapling stage, have been shown to grow faster in the presence of mycorrhizae. Mycorrhizae are of two types. *Brachystegia* woodlands are dominated by ectomycorrhizal tree species, while the drier or more eutrophic woodland types are dominated by endomycorrhizal species (e.g. *Colophospermum*, *Baikiaea*, *Burkea*) (Högberg 1986, Högberg & Piearce 1986, Munyanziza 1994). These symbiotic relationships are important in sustaining woodland productivity.

4.6 Fire

Low herbivory, high carbon content in the plant biomass, seasonality in litter decomposition and a long dry season (5–7 months) interact to create conditions in which fire plays an important role in nutrient cycling. One of the key features of the ecoregion is the frequent occurrence of dry season fires that are caused mainly by man. Annual fires tend to burn grass and woody litter and therefore do not usually add much to the accumulation of carbon dioxide in the atmosphere as emissions are recaptured the following year by annual regrowth.

Fire has been a component in the Miombo Ecoregion for at least 55,000 years (Davis 1971) when it was first used as a tool for hunting and shaping the landscape during the Early Stone Age. It is therefore one of the determinants of the ecoregion, which contains communities, both plant and animal, that exhibit variable tolerance to fire. The evolutionary effect of frequent fires has probably been the development of plant life forms, life histories and/or phenological cycles that avoid and/or minimize fire damage. Thus floristic diversity has to varying degrees been influenced by anthropogenic fire. Maintaining fire frequency in some communities within the ecoregion will be necessary for conservation of its biodiversity.

In some instances, fire, drought, impeded drainage and soil nutrient poverty have interacted to create unique plant communities, such as the chipya in Zambia and 'underground trees' (White 1976). However, frequent fires are destructive in some vegetation communities, such as the evergreen *Cryptosepalum* and riverine/swamp forests, and keeping fire out of them is critical to their continued existence.

4.7 Human Interactions

Significant human populations have inhabited the Miombo Ecoregion since the Early Stone Age, some 50,000–60,000 years ago, long before the introduction of food production technologies for both cropping and livestock. During the Early Iron Age, the ecoregion was subject to human occupation by people who hunted game, gathered wild vegetable foods and perhaps fished. Thus the interaction of man and biodiversity in the ecoregion dates back to pre-historic periods.

Because of the low soil nutrient levels, crop production has historically been based on various forms of shifting cultivation, involving fallowing that allows woodland to regenerate. This form of land use, including what is locally termed 'chitemene', has shaped the present day landscape cover over large parts of the ecoregion. Much *Brachystegia* woodland is largely secondary growth recovering from previous clearing by man. In this sense, the ecoregion can be considered a 'socio-ecological' system in which man has played a significant role in shaping the structure and composition of plant communities. This is one of the unique features of the Miombo Ecoregion and its future conservation will have to take into account this age-old human-ecosystem interaction.

5. SOCIO-ECONOMIC FEATURES AND PROCESSES

5.1 Socio-Economic Context

The outstanding feature of the Miombo Ecoregion is the existence of inter-linkages between biophysical features and processes on one hand, and socio-economic factors and realities on the other, in what has been termed the socio-ecological model. The socio-ecological nature of the ecoregion defines both the vision for the conservation of its biodiversity and the methodological approaches to be pursued.

Whilst conservation areas for the ecoregion are biologically defined, i.e. conservation targets are chosen on the basis of the biophysical characteristics, such as species diversity, endemism, etc., socio-economic variables tend to alter the biological parameters either positively or negatively. The very fact that the ecoregion straddles across national boundaries of 11 countries lends itself to peculiarities associated with policy and legislation pertaining to conservation. The positive and negative influences of socio-economic factors on the natural environment stems primarily from the dependence of humans on natural resources in pursuit of livelihood strategies. Such dependence stems from the historical and cultural linkages that have evolved over time. These linkages are characterised by feedback loops between people and the environment.

The role of socio-economic factors and processes within the ecoregion tends to be both direct and indirect, working at both the local scale and higher level scales. Human beings, the key socio-economic agents, tend to respond to both internal and external factors and forces in their interaction with the environment. These factors and forces include their history, culture, economic and political circumstances, institutional arrangements and natural phenomena. Their response to these stimuli in pursuit of positive livelihood paths determines the biophysical integrity of the natural resource base which supports the livelihood options. In essence, people, as economic and social agents, aim to maximise their welfare from the consumption of goods and services, which are primarily provided by the environment. It is in light of this relationship that we recognise socio-economic variables as being key to the conservation of resources in the ecoregion. The socio-economic variables can be both threatening or enhancing the conservation of the ecoregion and its biodiversity.

5.2 Key Socio-Economic Features and Processes

The socio-economic realities are driven by key features and processes. It is from these overarching features and processes that socio-economic threats and opportunities emanate. They form the linkages between the human and biophysical components of the ecoregion.

5.2.1 Socio-Political Factors

The Miombo Ecoregion covers over 3.8 million km^2 in 11 central and southern African countries of Angola, Botswana, Burundi, Democratic Republic of Congo (DRC), Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia and Zimbabwe. The human population in this area is estimated at 60 million, with an overall density of about 16 people per km^2 (Campbell 1996). Human population density over much of the ecoregion is therefore still low and patchy in comparison with other savanna regions of Africa under similar climatic conditions, although the situation is changing. The density of livestock is also relatively low. Reasons for this demographic situation are complex, but by and large reflect the interrelationships among geology, soils, plant production and quality, wildlife and disease.

The biophysical features of the ecoregion put constraints and limits on human use of natural resources and socio-economic development. Socio-economic processes in turn influence the biophysical features and processes of the ecoregion, and have done so since pre-historic times.

5.2.3 Cultural Processes

The Miombo Ecoregion has been inhabited for perhaps 3 million years (e.g. Broken Hill Man), although the effects of man perhaps date from only 60,000 years ago. These early humans hunted game and gathered wild vegetable foods. During the Middle Stone Age, human settlements expanded from the major river valleys and lake basins to areas on the plateau. As a result of these, most of the ecoregion has been subjected to human occupation by the end of the Middle Stone Age. There was a striving culture during the Late Stone Age about 15,000 years ago, followed by the introduction of food production technologies for both crops and livestock, as well as techniques of metallurgy, pottery and hut construction. These innovations were associated with the arrival from the Congo Basin of the Bantu-speaking Negroid people during the second to fourth century AD. These Bantu-speaking people co-inhabited the ecoregion with scattered groups of nomadic San (Bushmen) hunter-gatherers who wandered across the Central Africa plateau.

The evolutionary process developed an interdependence between humans and the environment, which is now embedded in the cultures of the peoples of the region. The two are thus inseparable, with humans depending on the environment for food, shelter, fibre, medicine and spiritual needs. Such a relationship to a great extent shapes the current socio-economic realities in the region.

Accelerated mixing of cultures occurred during the period 1500 to 1700 when a number of migrations from the Luba and Lunda empires of Katanga in the DRC moved into the central parts of the ecoregion (Davis 1971). From AD 1800 to 1900, major migrations from Katanga ceased and were replaced by a series of migrations from South Africa. This whole period was characterised, not only by widespread raids that greatly caused cultural disturbances in the ecoregion, but also by trade in slaves, metal products and ivory that was dominated by the Arab and Swahili peoples through Tanzania and Malawi and the allies of the Portuguese, the Chikunda in Mozambique and Mambari in Angola.

The widespread raiding activities of the 1800s and 1900s were only stopped by the arrival of colonialists from Europe, especially the British who established colonial administrations during the last decade of the 19th century. These interventions were marked by wide-ranging changes of institutional arrangements for the control of land and natural resources. With independence during the 1960s the new nationalist governments simply inherited institutions established by the colonial governments. Most of the conservation approaches in the ecoregion today are therefore deeply rooted in the colonial legacy.

5.2.4 Land Use and Socio-Economic Development

The main traditional form of land use in the ecoregion is cultivation of small fields of cassava, sorghum, millet, maize and pulses, either under some form of shifting cultivation involving ash fertilisation and hand tools. In drier areas, where tsetse fly and trypanosomiasis is not prevalent, livestock-rearing is the major form of land use. In spite of the relatively small human population, such extensive land use systems have modified, and continue to modify, the ecoregion through removal of woodland cover. After the Second World War, colonial governments encouraged the growing of cash crops, such as flue-cured tobacco and groundnuts. This was partly achieved by extensive programmes of tsetse fly eradication, thereby expanding land for agricultural production, which resulted in the widespread clearing of woodland in western Tanzania and Malawi for groundnut and tobacco cultivation (Rodgers 1996). Governments are still encouraging the growing of these and other new cash crops, causing continued woodland clearance in many areas.

Land use is clearly the main linkage between the social system and the biophysical. Traditional extensive land use patterns have involved dependence on natural resource harvesting, shifting 'slash and burn' cropping and livestock-keeping that is limited by water, grazing potential and trypanosomiasis. With an increasing human population and low level of socio-economic development, dependence on natural resources harvesting has increased, fallow cycles in shifting cultivation have become shorter, and the pressure to open more land for cultivation and livestock grazing has increased. From a livelihood perspective, the ecoregion is clearly important for the abundance of woodland products: wood for building, fuel, fibre and food (fungi, honey, edible insects). However, the availability of surface water has influenced human population densities, settlement patterns and movements, as it has done for livestock and wildlife.

While hydropower from large dams, such as Kariba and Cabora Bassa on the Zambezi River, are important sources of energy for mining and industry, most people in the region are dependent on wood for heating and cooking fuel. There is a growing long-distance trade in firewood and charcoal from rural to urban areas. Urbanisation and industrial activities such as mining are exerting additional pressure on the biological resources. In particular, the use of fuelwood and charcoal in urban areas has accelerated deforestation, while the growing trade in game products has resulted in overexploitation of the larger mammals that have a low reproductive rate, such as elephant and rhino. Over-fishing has become a common problem in many of the fisheries. Pollution from domestic urban and industrial wastes are also affecting water quality, and in some cases creating conditions for invasion by alien species. A number of aquatic ecosystems within the ecoregion have already been invaded by the notorious water hyacinth *Eichhornia crassipes*, an aquatic weed that adversely affects water quality, indigenous biodiversity and water transport.

Although agriculture is the dominant form of land use in the ecoregion, conservation and natural resources management under different regimes have evolved, and are being recognised as legitimate land uses to different degrees in different countries. This recognition is still growing especially for community-based forms of resource management and conservation. The colonial era and the period just after independence in most countries saw the designation and gazetting of several areas for conservation, mainly in the form of protected areas. These have, and continue to contribute to, the conservation of biodiversity in their own way. In recent years, growing recognition of the role that local communities play in the management of natural resources has led to community-based natural resources management (CBNRM) initiatives in the region. Private conservation initiatives, especially for wildlife, have seen the establishment of conservancies either involving private landholders only with or without adjacent communities. Transfrontier conservation and natural resources management is an evolving land use feature within the ecoregion. Thus conservation land use is currently being driven at two main fronts. One is the protected areas approach (mainly state-owned), while the other involves several incentive-led natural resource management and resource sharing arrangements.

It is estimated that state-owned protected areas within the Miombo Ecoregion comprises around 13% of the total land area (IUCN 1991, WWF SARPO GIS database). A full listing is not yet available, and is compounded by confusion on equivalent status between countries and extent of management for biodiversity. This figure includes National Parks, Game/Wildlife Management Areas (GMAs) and Recreational Areas, but does not include Forest Areas, protected areas in Afromontane parts of the ecoregion, CBNRM areas or large water bodies.

Game Management Areas form a significant part of the protected area network. They are areas where, although settlement is permitted, a major form of land use is hunting for meat or trophies. Both Zambia and Mozambique have large extents. In Safari Areas in Zimbabwe settlement is not allowed, and they are regarded similar to National Parks. Community-based natural resource management (CBNRM) areas are mostly districts where the local authorities are actively permitting utilisation of natural resources such as wildlife and timber but on a controlled sustainable basis. Significant areas are found in Zambia, Zimbabwe and the Caprivi Strip of Namibia. Forest Areas are state-controlled and are used for either catchment protection (especially Malawi and Zambia) or for commercial timber extraction. Some are also used for trophy hunting. Very often they are important areas for biodiversity conservation, both of species and ecological processes. A map of all categories of protected or utilisation areas is given in Figure 5, and extent is given in Table 3.

Although current protected areas may address some of the threats to identified conservation targets, they do not address some other threats, especially those to the underlying ecological processes that maintain the integrity and resilience of the woodland system. The large national parks of the region tend to be at lower elevations and in river valleys, for example, not in catchment headwaters. Dambos, wetlands, river valleys and riparian areas are key habitats within the ecoregion for both species and processes, but their conservation depends upon maintaining a level of woodland cover above some unknown threshold value in order to preserve natural hydrological functioning.

Table 3. Protected areas within the Miombo Ecoregion.

Protected area type	**no. areas**[1]	**total extent** (km^2)[2]
National Parks	62+	238,610
Game Management Areas	21 [3]	234,463
Forest Land	70	98,139
SUBTOTAL		571,212
CBNRM areas	32+	38,406
Private conservancies		
Transfrontier areas	7?	
TOTAL		609,618

Source: WWF-SARPO database.
Notes: 1. Includes all areas with at least part of their extent within the Miombo Ecoregion.
2. Figure excludes montane protected areas and those with a significant proportion outside the Miombo Ecoregion (e.g. Kruger National Park).
3. Figure is low as adjacent GMAs have been regarded as one.

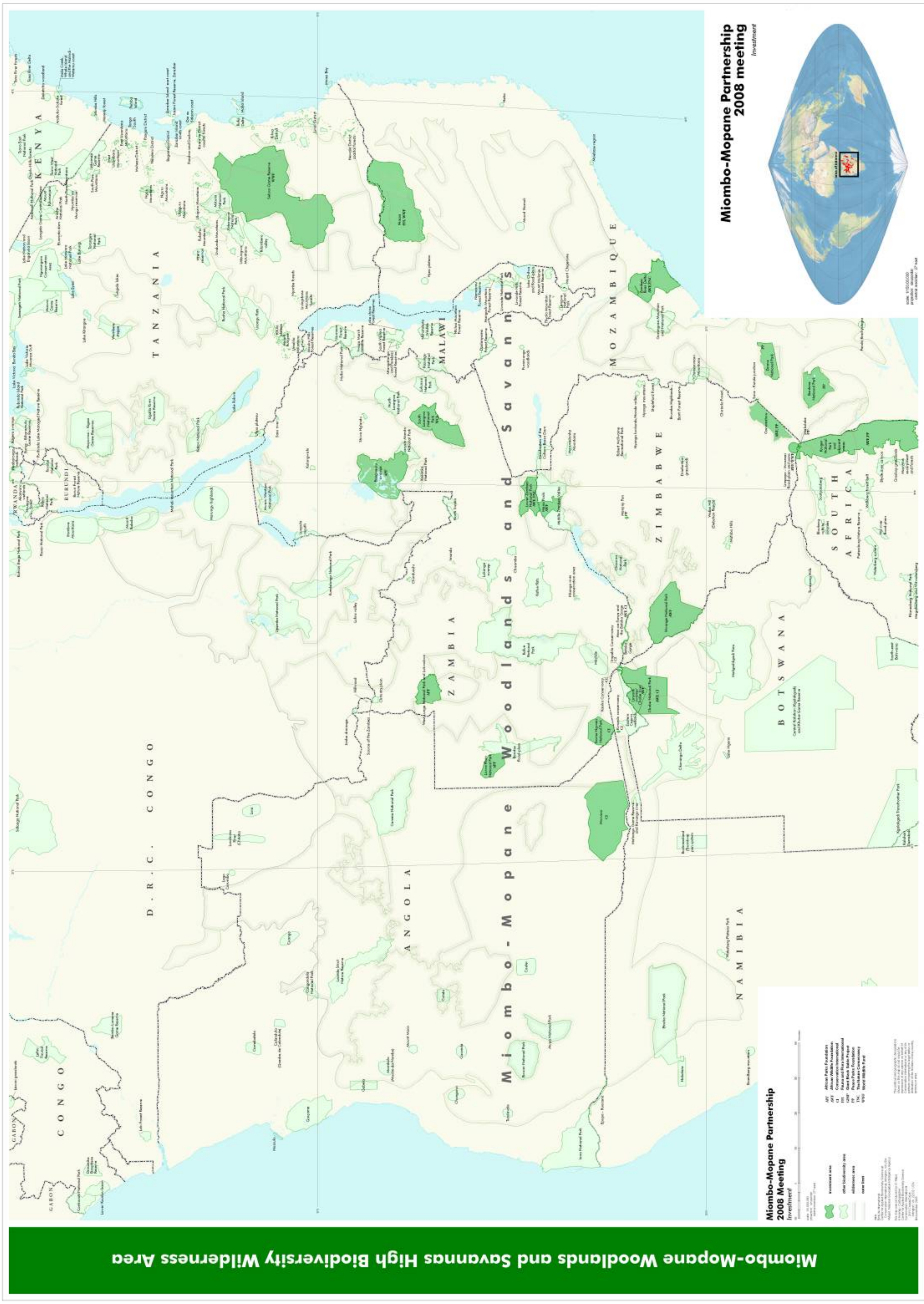

Figure 5. Miombo Ecoregion – protected areas (from CI, unpublished 2008)

The protected area network tends to be concentrated in low-lying arid areas of marginal value for agriculture or settlement. Disease (especially sleeping sickness) was a major constraint in the past to human settlement. Many such areas are found close to national borders, which has given rise to the concept of Trans-Frontier Conservation Areas (TFCAs). A number of these are found within the ecoregion (Cumming 1999), including the Gaza–Kruger–Gonarezhou in SE Zimbabwe/NE South Africa/S Mozambique), the Four Corners centred on the eastern Caprivi Strip, and the Niassa–Selous area of S Tanzania/N Mozambique.

A full listing and analysis of protected area coverage has not yet been carried out, but many of the 26 identified biologically-significant areas incorporate existing National Parks and GMAs, and some also incorporate possible TFCAs. The major significant areas lying predominantly outside protected areas are Western Angola, Zambezi headwaters, Upper Zambezi, Great Dyke, Upper Shire/Eastern Rift, Copperbelt, Lake Mweru/Luapula, Bangweulu swamps, Moyowosi and Itigi thicket. It is recommended that a gap analysis of coverage of existing protected areas for both the ecological processes and biogeographic/taxonomic elements of biodiversity is carried out.

5.3 Economic and Policy Environment

The Miombo Ecoregion is made up of countries which are at different stages of development, but are generally in the developing countries category. These are characterised by unfavourable economic and development indicators, such as low incomes, poverty, unstable economies, dependence on primary agricultural production, negative terms of trade, low investment, etc. Economic reforms, such as the World Bank and IMF's economic structural adjustment programmes, are underway in some of the countries, and have several impacts on people and the environment. This economic context has affected the relative welfare of people in the region at individual, national and regional levels, and has also affected the role that governments play in the provision of social services. It has also affected conservation and protection of the region's natural wealth through the policies that governments put in place for the sake of the environment and the people's welfare. Different policies and legislation on the environment, including access to resources and land tenure regimes, are in place in different countries. Most policies have tended to negate the role that local people can play in the conservation and management of natural resources. The extent to which investment policies address environmental concerns is also inadequately addressed, but is changing within the region. More information is required on the state of policy and legislation affecting biodiversity conservation in the region, and the extent to which these are harmonised to either enhance or threaten conservation efforts.

5.3.1 Socio-economic Threats and Opportunities

The identification of socio-economic factors (threats and opportunities) creates the opportunity to develop conservation programmes at both local and policy levels, both at specific sites and on an ecoregion scale. Within an ecoregion that is significantly driven by socio-economic factors, key agents such as governments, local people, existing institutions and other stakeholders can be influenced to both reverse negative impacts and to foster positive trends. In a socio-ecological system, such as the Miombo Ecoregion, it is necessary to maintain the balance between human benefit from the available resources base and the capacity of the biophysical components to recover from human and natural induced change and stress. This provides the incentive for both components to support each other. Such a balance requires the identification of system features that are resilient and able to tolerate stress and change without collapsing, as well as features that are vulnerable to collapse. Equally important is the need to identify factors threatening and enhancing the conservation of these system features. In essence, biodiversity conservation goals cannot be realistically established and achieved without consideration of human livelihoods and well-being.

During the visioning process, specific threats and opportunities were identified in the ecoregion, and attempts were made to represent these on maps of the ecoregion. The steps followed in the identification and mapping of threats and opportunities are:

- Developing linkages between the human component and the environment, thereby identifying variables on the interface between the two (key drivers)
- Identification of cross-cutting issues and their categorisation
- Identification of opportunities and threats from these issues, including underlying causes
- Rank the opportunities and determine which could be mapped
- Developing proxies to use for mapping threats and opportunities that are not mappable
- Identification of base maps to use for the mapping of priority opportunities and threats
- Map out areas in which identified threats and opportunities occur or have potential in the ecoregion.

However, because of poor data availability and representation from all countries of the ecoregion, the mapping of threats and opportunities remained with gaps that would need to be filled.

5.3.2 Cross-cutting Factors

Some threats and opportunities and their underlying causes are cross-cutting. These include:

- Macro-economic environment and economic reforms
- Poverty
- Wars and civil unrest
- Breakdown of traditional and social structures among communities
- Natural resources management structures among institutions
- Social cohesion
- Recognition of local capacity to manage resources.

These factors form the socio-economic drivers. They may not individually be traced to specific locations, i.e. may not be subject to mapping, but may influence the human-environment interactions at particular sites.

5.3.3 Threats

Landscape-scale threats to biodiversity include woodland clearance and the consequential changes in hydrological and ecological processes. For the foreseeable future (up to 50 years) peoples of the region will continue to be highly dependent on natural resources given the low levels of economic development. If they do not benefit from alternative uses of the resources that support conservation, they will be more likely to increase their harvest and exploitation of the resources in order to survive, thereby worsening the integrity of the same resources. Examples of such behaviour include clearance of vegetation for cultivation, leading to loss of woodland cover. This is the most important threat to the ecoregion, and the consequential loss of hydrological and ecological functions would tend to have a cascading effect on biodiversity conservation. Woodland loss should be seen as the key threat to all of the conservation targets in the ecoregion.

The proximate causes of woodland cover loss are:

- Rising poverty, unemployment, hunger and debt
- Increase in demand for, and use of, natural resources
- Mis-governance, corruption and rent-seeking by government institutions
- Perverse national economic incentives, including agricultural pricing policies, that encourage land clearance
- Refugee movements and settlements
- Inadequate property rights.

These proximate causes in turn are caused by root (ultimate) causes, such as:

- Population growth
- Inequitable land and resource access and tenure
- Economic stagnation
- Weak government institutions
- Civil unrest and war.

Though many socio-economic factors threaten the ecoregion, five key threats were identified and mapped during the visioning process:

- Agricultural expansion
- Population density and growth
- Infrastructural development
- Deforestation – distinguished from deforestation due to agricultural expansion because of the peculiar socio-economic factors driving it
- Competition for water.

These are addressed individually below.

Agricultural Expansion
70% of the ecoregion is under small-scale agriculture. Rural farmers will thus play a key role in determining the fate of the landscape. The region depends heavily on agriculture to the extent that continued demand for food and raw materials will be met by increasing areas under cultivation. Agricultural expansion transforms forest land into agricultural land, leading to total loss of species and vegetation. Current and potential agricultural expansion in the region is in tobacco and cotton growing areas, in areas converted from large-scale commercial farming to small-scale farming. Areas with good soils and high rainfall (> 800 mm/year) are also threatened by agricultural expansion, as are areas where population densities are high. Several factors, including macroeconomic reforms, agricultural commodity pricing policies, agrarian reforms, support for the agricultural sector (currently low), do influence agricultural expansion. However, these factors are not subject to mapping.

Population Density
Areas with high population densities of greater than 10 persons/km^2 are threatened by human pressure. Demand for natural resources and environmental services is highest in highly populated areas. The population density map indicates areas that are most highly threatened.

Infrastructural Development

Development of infrastructure is accompanied by destruction of flora and fauna and their ecosystems, thus disturbing their processes. This threat is high in a region whose infrastructure is still developing. Mappable infrastructural developments threatening the biodiversity of the Miombo Ecoregion are:

- Lakes
- Cities and other urban and business centres
- Major roads and railways
- Electricity grid lines
- Mineral deposits.

Deforestation

Apart from agricultural expansion, deforestation arising from other socio-economic drivers is a major threat to the ecoregion and its biodiversity. Examples of such drivers include:

- Charcoal and firewood making
- Illegal logging
- Fish smoking and tobacco curing (in some areas)
- Refugee areas
- Unsustainable wildlife levels, e.g. elephants
- Deforestation in dambos.

Competition for Water

The demand for water is going to increase in the foreseeable future as population and economic development progress. As such, competition for water for both human and ecological functions is forecast to increase. Competition will be high between upstream and downstream users and uses of water, especially competition for uncontaminated water. The competition for water for different uses is an important threat as water is critical for ecosystem functions. However because of knowledge gaps, more information is required in identifying threatened areas.

5.3.4 Opportunities

In spite of the many threats to biodiversity conservation in the ecoregion, opportunities exist for improving the current situation and for innovative approaches to be implemented. Socio-economic opportunities provide a niche and competitive edge against which conservation actions can be implemented. Socio-economic factors that provide opportunities in priority conservation areas enhance the implementation of initiatives. In fact, they lend themselves as platforms on which conservation efforts may be built. Opportunities identified by the visioning process include:

- Food security coping strategies among communities living with resources
- Increased capacity to build local level capacity to manage natural resources
- International, regional and sub-regional processes and agreements
- Sustainable use and expanded markets for non-timber forest products
- Non-agricultural forms of land use.

Food Security Coping Strategies

Food-coping strategies have the potential to reduce demand for agricultural land and excessive demand for forest products. These include drought-tolerant crops, employment and income opportunities, use of traditional foods to supplement agricultural production, and poverty alleviation programs. Most countries in the region have developed or are developing poverty reduction strategies for implementation with assistance from the World Bank. Poverty is one of the proximate causes of woodland cover loss in the ecoregion, and poverty reduction can open wider opportunities for biodiversity conservation.

Increased Scope for Building Local-level Capacity to Manage Natural Resources
The nations in the ecoregion are implementing CBNRM programmes and appropriate land tenure arrangements for these. Low population density also provides opportunities for expanding existing CBNRMs. The ecoregion has existing and potential TBCAs that can be used for the conservation of wildlife across international borders.

*International, Regional and Sub-regional Processes and Agreement*s
Existing agreements and processes concerning conservation of biodiversity in the ecoregion are an important policy opportunity for enhancing the conservation of natural resources. These include the SADC protocols, Trans-border natural resources management programs, World Heritage sites and the existing protected areas network, SADC shared watercourses protocol and numerous other international conventions.

Sustainable Use and Expanded Markets for Non-timber Forest Products (NTFPs)
There are a number of NTFPs in the ecoregion with potential for increased and sustainable use and expanded markets. These include mushrooms, indigenous fruits and products, caterpillars, honey, game, crafts and carvings. The sustainable use of these products can reduce landscape cover change and increase chances for the successful implementation of biodiversity conservation.

Non-agricultural Land Use
Non-agricultural land use offers an opportunity for generating incomes from non-agricultural products, such as wildlife, tourism, bee keeping and forest plantation products. Promotion of such non-agricultural land uses will reduce loss of woodland cover and thereby provide and increase opportunities for biodiversity conservation.

6. CONSERVATION VISION AND AREAS OF BIOLOGICAL IMPORTANCE

6.1 Vision Statement

In 50 years the peoples and nations of the region would like to have:

"***A biologically diverse and ecologically functional Miombo Ecoregion that meets and sustains human needs and development through the sustainable use of natural resources, landscapes, species and environmental processes, thereby providing both the resources and the incentives for conserving biodiversity.***"

The workshop understood that "biologically diverse" signifies the maintenance of existing levels of species diversity and the number and status of endemics.

6.1.1 Rationale

The biophysical features and processes that maintain ecological resilience and integrity in the Miombo Ecoregion include:

- Complex surface/subsurface hydrological processes that lead to slow release of water from watersheds and catchments and delayed or regulated water flow in major rivers
- Regulatory function of woodlands in hydrological processes and nutrient cycling
- Mosaic of habitats at several scales, including the broad landscape scale
- Mobility of organisms between habitats/landscape units including humans, livestock and wildlife
- High carbon landscape in which carbon sequestration maintains integrity and resilience and influences microbial processes, nutrient cycling and vegetative regeneration
- Dominance of megaherbivores with episodic outbreaks of insect herbivores
- Interrelationship of hydrology, wildlife movement, and human settlements
- Fire.

The ecoregion contains a number of unique or important habitats or communities, it is a centre of Caesalpinoid diversity and supports unique 'underground' trees, a high fungal and termite diversity, and a number of keystone vertebrates such as elephant, buffalo and hippo. The ecoregion is also important for carbon storage and sequestration, as well as for the albedo-reducing effects of its extensive woodland canopy cover.

Perhaps the key socio-economic feature of the Miombo Ecoregion is the prevalence of livelihood strategies based on indigenous knowledge and land use systems. These are adapted to low population densities over a wide biogeographic area. Low nutrient and protein systems, widespread use of timber and non-timber forest products and seasonal movements of livestock and wildlife also characterise the area. Thus conservation in the ecoregion should seek to maintain and sustain:

- Biophysical features and processes that maintain ecological resilience and integrity
- Ecological processes that produce essential goods and services that sustain human livelihoods

- Existing species diversity and levels of endemism
- Unique habitats, communities and landscapes
- Human livelihoods and social systems, norms, and the knowledge that allows the biophysical system to be sustained
- Other features of global importance, such as carbon storage and sequestration processes.

6.2 Areas of Importance for Biodiversity Conservation

Regional specialists at the September 2001 Vision Workshop identified a number of areas of importance for different taxa. The process of area determination was based principally from a series of maps produced earlier for WWF-SARPO by the Biodiversity Foundation for Africa (later published as Timberlake *et al.* 2011). They covered, for a range of taxonomic groups (plants, large mammals, small mammals, birds, herps, fish, dragonflies, butterflies), areas of high species diversity, endemism, threatened species, important populations of various groups, areas of evolutionary significance, and areas important for movement or migration. Areas determined by the workshop for each taxonomic group or feature were roughly drawn on regional maps. Following this, working groups amalgamated the overlying polygons for each taxonomic group to form 22 areas of biological significance, many of them transboundary, and these were provisionally described.

Over the period February to April 2002 a series of national workshops were held, incorporating national biological, socio-economic and conservation specialists. They were held in Lusaka (covering Zambia and the Congo), Dar es Salaam (covering Tanzania), Harare (covering Zimbabwe, Botswana and Namibia) and Maputo (covering Malawi and Mozambique). During the national workshops the relevant selected areas were carefully assessed both biologically and from a conservation/socio-economic perspective, and boundaries redrawn if necessary. In some cases areas were split into two. Additional biological information was recorded along with any conservation threats and opportunities. The output from these workshops is shown in Figure 6 and described below. Major taxonomic attributes are shown in Table 4.

It should be stressed that their boundaries are approximate and have not been carefully demarcated. There has also been no attempt to prioritise them with respect to each other. More careful analysis of the relative importance of the different taxonomic groups and processes is still required, and a more careful assessment of threats, opportunities and appropriate conservation actions is needed.

1. WESTERN ANGOLA

An extensive and poorly documented area covering much of Huila, Huambo, Benguela and Bié provinces in western Angola. It includes the high plateau above the escarpment comprising wet and dry miombo woodland, high altitude grassland, and patches of moist forest and escarpment woodland. Part of the proposed area is situated on the margins of the Miombo Ecoregion (including the biologically-rich Angolan escarpment) and it includes areas perhaps better incorporated in adjacent coastal or forest ecoregions. More information is required on this area, both in terms of its extent and its biological attributes.

Many of Angola's 1260 endemic plant species are said to be found here and along the escarpment. The endemic giant sable antelope is restricted to the area around the Luando Game Reserve. A number of miombo endemic birds (e.g. Pale-billed Hornbill, Boehm's Flycatcher) are found in the Huambo highlands, while at least five globally endangered bird species are restricted to the escarpment at the edge of the ecoregion. The upper Cunene river system in the south is rich in fish (63 species), of which 13% are endemic.

Three protected areas are incorporated – Bicuari, Mupa and Luando – but their current status is not known.

Table 4. Areas considered to be of importance for conservation in the Miombo Ecoregion, along with taxonomic interest.

no.	Area	plants	mamm.	birds	herps	fish	inverts	animal move.	other ERs
1	Western Angola	×	×	×		×			×
2	Zambezi headwaters	×	×	×	×	×	×		×
3	Upper Zambezi	×	×	×	×	×		×	
4	Kafue Flats		×	×		×			
5	Four Corners		×	×	×	×	×	×	
6	Mid-Zambezi valley	×	×	×	×			×	
7	Great Dyke	×							
8	Matobo hills	×	×	×			×		
9	Shashe/Limpopo valley	×		×	×			×	
10	Gaza/Kruger/Gonarezhou	×	×	×	×	×		×	
11	Manicaland/Nyanga	×		×			×		×
12	Manicaland/Chimanimani	×	×	×	×		×		×
13	Gorongosa/Marromeu	×	×	×	×	×	×	×	×
14	Luangwa valley/Kasungu	×	×	×			×	×	
15	Mzimba/Nkotakota	×		×		×		×	×
16	Upper Shire/Eastern rift	×	×	×		×	×	×	×
17	Lower Shire/Western rift	×	×	×		×			
18	Copperbelt	×					×		
19	Upemba/Kundelungu	×	×	×	×	×	×	×	
20	Lake Mweru/Luapula	×		×	×	×	×	×	
21	Bangweulu swamps	×	×	×	×		×		
22	Moyowosi	×	×	×	×	×	×	×	×
23	Rukwa valley		×	×			×	×	×
24	Itigi thicket	×					×	×	×
25	Selous/Kilombero	×	×	×	×		×	×	
26	Lower Rovuma	×	×					×	×

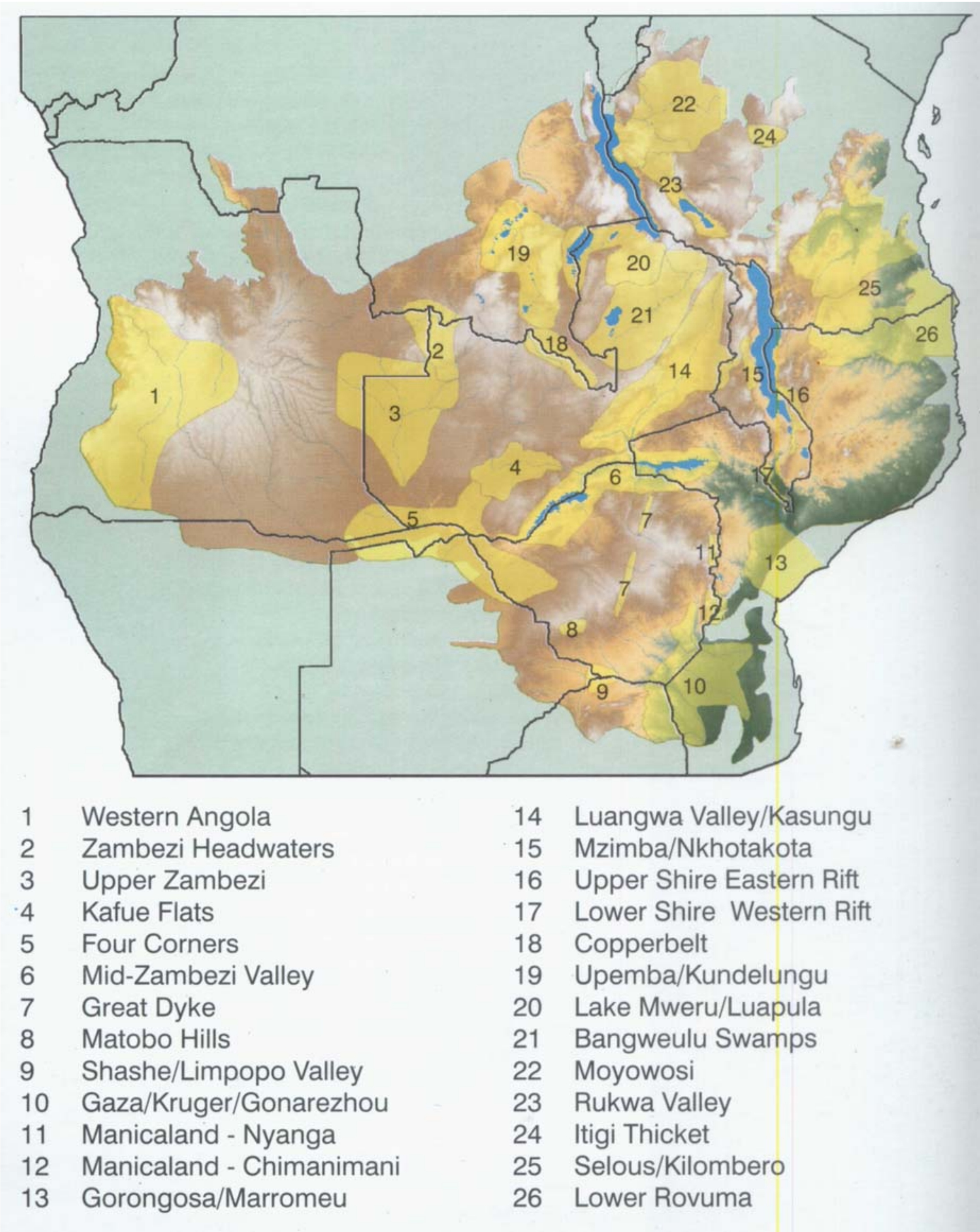

Figure 6. Miombo Ecoregion – areas of particular conservation interest (from WWF SARPO 2003).

2. ZAMBEZI HEADWATERS

An area along the Zambezi–Congo watershed in NW Zambia and southern DRC. It includes a broad swathe each side of the Congo–Angola and Congo–Zambia borders incorporating relatively flat country, and in Zambia it also includes the Ikelege pedicle and much of

Mwinilunga district extending down to West Lunga. The area is a transition zone between the Miombo Ecoregion and the Congolian rainforest ecoregion. It is very diverse with species from both regions. The main vegetation type is wet miombo, but there are significant inclusions of dambo grassland, swamp, swamp forest and dry evergreen forest, including that dominated by *Cryptosepalum*. Chipya (*Acacia–Combretum* woodland) is also present.

Plant diversity is very high in a small area (around 1000 woody species) owing to a mixture of Zambesian and Congolian elements, and there at least 53 species of restricted distribution (possibly endemic). The area has high small mammal diversity and four endemics (*Crocidura ansellorum*, *Malacomys australis*, *Rhinolophus* sp. nov., *Graphiurus monardi*). Bird diversity is high with many species of Congolian affinity (e.g. African Wood-pigeon, Honeyguide Greenbul). A rich herpetofauna (57 reptiles, 35 amphibians) includes Congolian elements. Fish diversity is high, as elsewhere in the upper tributaries of the Zambezi. Both butterfly diversity and endemism are high (e.g. *Euptera freyja*, *Spindasis pinheyi*, *Kedestes pinheyi*), and the area is very rich in dragonflies.

There are no protected areas except for the West Lunga National Park in the south and several small Forest Areas in Zambia. The Ikelege pedicle is a National Heritage site. Protected status in the DRC and Angola is not known.

The area is important for hydrological processes and for water catchment protection. It is also as a carbon sink. The major threat is severe deforestation, much of it associated with refugees fleeing the instability in Angola and the DRC resulting in much new settlement and over-exploitation of natural resources, including game animals. Uncontrolled bush fires are also a problem. There is significant apicultural potential, but debarking of *Brachystegia* trees to make hives is a threat in some areas. Various community-based afforestation schemes using indigenous species are in place.

3. UPPER ZAMBEZI WOODLANDS & FLOODPLAINS

An extensive area of wetland, grassland, *Baikiaea* woodland, wet and dry miombo woodland and *Cryptosepalum* forest on Kalahari sands in western Zambia and adjacent eastern Angola, extending from Senanga north through Mongu and Zambezi into Angola, and incorporating the Liuwa and similar plains. It covers the Zambezi (Bulozi) floodplain, pans and surrounding level plateau of the middle reaches of the Upper Zambezi.

There are 80–100 plant endemics or species with their core distribution in the area, particularly woody suffrutices. A significant proportion of the total extent of *Cryptosepalum* forest is incorporated. The only true mammal migration in the ecoregion – of wildebeest – occurs between the Liuwa plains and eastern Angola, an area that also supports good populations of roan antelope, tsessebe and wild dog. The grasslands contain a number of isolated populations of *Cisticola* warblers, possibly undergoing speciation, and the wetlands support a high waterbird diversity and abundance. Significant numbers of Wattled Crane are found. A rich herpetofauna (70 reptile and 34 amphibian species) reflects a mixture of Congolian, Kalahari, miombo and East African elements. There are five endemic reptiles (*Typhacontias gracilis, Typhlosaurus jappi*, *Zygaspis nigra*, *Dalophia ellenbergeri, Rhamphiophis acutus jappi*) and an endemic frog (*Hemisus barotseensis*). The Upper Zambezi, of which this area is a core component, has been an important centre for fish evolution, and the ichthyofauna is still largely intact, with a high diversity of 90 species.

The Liuwa Plains National Park is included and a significant portion in the west of Zambia is a Game Management Area. A number of small protected forest areas are included. The conservation status in Angola is not known.

Major threats are deforestation, extensive regular fires and overgrazing in places. The Bulozi plain area is an important rangeland with high cattle numbers. Other localised threats include illegal logging for *Baikiaea* and *Pterocarpus angolensis*, overfishing and commercial rice production in some of the tributary dambos.

4. KAFUE FLATS

An area of south central Zambia centred on the Kafue Flats, including the southern section of the Kafue National Park and adjacent Game Management Area (GMA). The main vegetation types are wetland and floodplain grassland, but there are significant adjacent areas of miombo, *Acacia–Combretum* and mopane woodland. It runs from the immediate western catchment of Lake Itezi-Tezhi, along the floodplain of the Kafue River to Kafue township.

The area contains important wetland habitat, although the floodplain and extent of flooding have been greatly modified by the construction of the Itezi-Tezhi dam. An threatened endemic antelope, the Kafue lechwe (a subspecies, although possibly a full species), is confined to the flats, and is declining in number. Important local seasonal movements of lechwe, zebra and waterbuck also occur on the floodplain. The floodplain, wetland and pan areas are of international significance for the seasonally high numbers of waterbirds, both in terms of numbers of species (>60) and numbers of individuals, that are found there, including significant numbers of Wattled Crane. There is one endemic killifish (*Nothobranchius kafuensis*) found in seasonal pans.

The area incorporates two small national parks on the floodplain, Blue Lagoon and Lochinvar, the southern part of Kafue National Park, and an adjacent GMA.

Pressures on the Kafue floodplain are great, mostly through hydrological changes resulting from dam construction, but also from heavy fishing levels and inappropriate fishing practices, illegal hunting of antelope, deforestation of parts of the immediate catchment, commercial sugar plantations just outside to the south, agricultural pollution and infestation by aquatic weeds. Severe competition for water from the Kafue River and the presence of a major urban centre – Lusaka – close by, exacerbate these threats. Human population pressures are high. However, there is substantial tourism potential. In the west there is a GMA, and a CBNRN project is in place.

5. FOUR CORNERS

An extensive transfrontier area, mostly on Kalahari sand, spanning the East Caprivi, northern Botswana, southwest Zambia up to the boundary of the Kafue National Park and northwest Zimbabwe south to northern Tsholotsho communal land and east to the Gwayi River. The vegetation is mostly *Baikiaea* and mopane woodlands, with smaller areas of dry miombo, *Burkea–Terminalia* and *Acacia* woodland, grassland and wetland, and riverine woodland along the Zambezi. It is the mosaic of woodland, grassland and wetland that provides much of the biological significance. Additional features of interest are the fossil Pleistocene dune fields that cover part of the area, and the fact that the Kazungula/East Caprivi area was the focal point for the palaeo-drainage of the Upper Zambezi before river capture.

The large mammal fauna is relatively intact and very diverse, with good populations of large herbivores (elephant, hippo, black rhino, white rhino, buffalo) and predators (lion, leopard, cheetah, wild dog). There are about 160,000 elephant in the area, about a quarter of Africa's total elephant population. Species present of restricted distribution include sitatunga, puku and Red lechwe antelope. Endangered species include black rhino and wild dog. There are significant movements of megafauna across international borders, particularly between the Hwange/Matetsi complex and Chobe where 10 corridors have been identified (for elephant, hippo, buffalo, zebra, wildebeest). There is a suggestion that elephant movement between the Four Corners and Kafue National Park should be restored. The high bird species diversity (over 500, including 63 raptor species), includes significant populations of Ostrich and Kori Bustard. The total world population of Black-cheeked Lovebird is found in the area close to Kafue National Park. Palaearctic migrants are common, particularly on seasonal pans. Two areas of high herp diversity are incorporated with over 81 species of reptile and 30 amphibians, including species typical of the Kalahari. The area forms part of the upper Zambezi system with a high fish species diversity. There is one endemic fish (*Nothobranchius* sp.) in pans in the East Caprivi. The area along the Zambezi below Kazungula is rich in both Odonata and Lepidoptera with at least two endemics.

The four corners incorporates a number of protected areas – Chobe, Hwange, Zambezi, Matetsi, Kazuma Pan, Sioma-Ngwezi and Mamili. A trans-frontier conservation agreement is being put in place, and the area has high tourism potential, particularly for conservation business ventures.

Economically, tourism is particularly important, with major centres in Victoria Falls/Livingstone, Hwange National Park and Chobe. Major threats are plans for water extraction from the Zambezi (although this is most likely to occur further downstream), regional security issues (in Angola and the Caprivi Strip), and conflicting land uses. This includes problem animal control in some areas, and conflicts in communal lands in Zimbabwe and the East Caprivi. There are, however, numerous CBNRN projects in Zimbabwe, East Caprivi and northern Botswana. Poaching is problematic in places. Timber extraction was a major industry in the past, and unsustainable logging for *Pterocarpus angolensis* and *Baikiaea plurijuga*, particularly in Zambia, is a major concern.

6. MID-ZAMBEZI VALLEY

A low-lying area along the Zambezi river from the upper end of Lake Kariba to the Cabora Bassa dam wall, encompassing the Zimbabwe/Zambia border and part of northwest Mozambique. The area includes the Zambezi escarpment and part of the plateau to the north of lakes Kariba and Cabora Bassa. Most of the vegetation is mopane woodland, with dry miombo on the escarpment and riverine woodland on alluvium along larger rivers. The area includes important patches of the regionally-threatened *Combretum–Xylia torreana* dry forest/thicket, and some significant pans.

There are probably 1500–2000 plant species, including 8–10 endemics, reflecting the wide range of habitats. The mammal fauna is relatively intact with a very diverse large mammal fauna, including predators (lion, cheetah, leopard), major populations of elephant (17,000+), hippo (2000+) and buffalo, and a small concentration of black rhino. Significant local movements of elephant occur. Over 400 bird species have been recorded, including important breeding populations of Carmine Bee-eater, Rock Pratincole, Lilian's Lovebird and African Skimmer. There are two Important Bird Areas (IBA) – the Mavuradonha mountains IBA containing a significant number of biome-restricted species, and the Mid-Zambezi Valley IBA with over 1% of the global population of Rock Pratincole, African Skimmer and Carmine Bee-eater. The Angolan Pitta is locally common in thickets. Lake Cabora Bassa appears to be an important over-wintering site for some migratory species. There is some altitudinal movement of birds up and down the escarpment. The Zambezi River, lakes Cabora Bassa and Kariba are important breeding areas for the Nile crocodile.

A number of protected areas (Chete, Matusadona, Charara, Hurungwe, Mana Pools, Sapi, Chewore, Dande, Lower Zambezi) are incorporated within the area, and also a number of CBNRM areas (Binga, Omay, Guruve in Zimbabwe, and Tchumo Tchato in Mozambique). However, there is no formally protected area in the Mozambique portion.

The two large recreational man-made lakes are important areas for tourism, both regional and local. There is great tourism potential, especially associated with these lakes and the Zambezi. In addition, both lakes are very important fisheries for both the local population and commercially (the latter principally for the introduced pelagic kapenta). An incipient trans-frontier conservation agreement is being negotiated, but in the meantime cooperation between adjacent districts is beginning in the form of wildlife management and utilisation.

The major threats are the rapid expansion of agriculture, particularly cotton production, outside protected areas, mostly resulting from development projects and tsetse control. Massive changes in hydrology and flooding regimes resulted from the construction of various dams on the Zambezi and its tributaries, and plans exist for an additional dam on the downstream edge of the area (Mepanda Uncua). Construction of veterinary fences is disrupting wildlife movement and precluding some land use options. Fragmentation of habitats, particularly for large mammals, is seen as a problem, while fish populations are threatened by both changes in hydrology and chemical pollution. Various CBNRM projects are creating pockets of resulting increasing welfare, and wildlife (safari hunting) is increasingly being seen as a viable land use option.

7. GREAT DYKE

The Great Dyke is a prominent, almost straight geological formation outcropping across the middle of Zimbabwe in a NE–SW direction. There are two distinct sections, north and south. The northern section lies north-east of Harare, while the longer southern ection loies west of Gweru and Kadoma. Much of the Dyke consists of ultrabasic serpentine rocks, hence the derived soils have an inverted Mg:Ca ratio that causes them to be toxic to many plants. Species have to be specially adapted. The vegetation on the mineral-toxic soils is grassland, with *Acacia* woodland on other clay soils and *Brachystegia–Julbernardia* woodland on the adjacent granite. Hydromorphic grasslands on vertisols are found nearby.

There are 20–30 endemic species of plant, most of which are found on the northern section, while only four species are confined only to the southern section. Mammal, bird and herp populations are not particularly special. Threatened species include the palm *Raphia farinifera*, confined to a few streamsides in the north, and succulents such as *Euphorbia nemoralis* and *Aloe ortholopha*, sought after by collectors.

There are no significant protected areas, except for two small Botanic Reserves for palms in the north and the Mavuradonha Wilderness Area on the edge of the Zambezi Valley. Most of the area is privately owned.

Settlement and agriculture on the Great Dyke itself are minimal owing to unsuitable soils, but there is much small-scale and large-scale commercial mining for chrome and platinum, respectively. Small-scale mining and mine dumps do not pose a significant threat, but vegetation clearance associated with large mine complexes and fire do. On the fertile, non-toxic, adjacent areas, woodlands are cleared for grazing and wood. Potentials for ecotourism are good, especially in the more scenic northern section.

8. MATOBO HILLS

An eroded granite batholith in western Zimbabwe, south of Bulawayo, giving rise to a series of rocky hills and bare rock interspersed with *Burkea–Terminalia* woodland and grasslands. There are small patches of mopane woodland and gully forest. In the eastern part there are important seeps and wetlands with peat.

There are five endemic plant taxa (*Cyphostemma milleri*, *Lobelia lobata*, *Maytenus heterophylla* subsp. *puberula*, *Triaspis dumeticola*, *Turrea fischeri* subsp. *eyelsii*). The wetter eastern section contains significant outlying populations of a number of forest and mesic species, more typical of E Zimbabwe, as well as wetland species, both very unusual this far west in the region. The area has a high density of medium-sized predators including leopard and various raptors, with one of the highest densities worldwide of breeding Black Eagle. It is the predator-prey relationship based on a high density of rock hyrax that is particularly unusual. Protected (introduced) populations of Black and White Rhino are also found. There is a high species richness of Odonata and Lepidoptera.

The Matopos National Park forms the central part of the area, but a significant portion is commercial farmland, with communal land on the southern margin. There are a number of very important cultural sites in the area, leading to its proposal as a World Heritage site. Tourism is well developed, but there are land use conflicts at the margins of the area resulting from increasing human and livestock populations, which has led to various CBNRM initiatives. The Matobo hills are an IBA.

9. SHASHE / LIMPOPO VALLEY

A relatively small transfrontier area centred on the confluence of the seasonal Shashe and Limpopo rivers in SW Zimbabwe/NW South Africa/E Botswana. The vegetation of the hot, dry area of low rainfall is mostly mopane woodland, but the key habitats are woodland/shrubland on Karoo sandstone hills and riparian woodland.

There is a small population of elephant moving between the three countries, and moderate populations of other wildlife. Total plant species diversity in the Zimbabwe section is over 100 species with at least two endemics/near endemics (*Jatropha loristipula*, *Pavetta gwandensis*). The are contains some of the most extensive and best developed riparian woodland forest in this section of the Limpopo valley. An Important Bird Area, the Vhembe Nature Reserve, is situated in the South African portion, which supports significant populations of waterbirds on the floodplain, and a significant number of nationally and globally threatened bird species. The Shashe/Limpopo area is a centre of diversity for reptiles, containing relict populations of Kalahari species such as Horned Adder and Barking Gecko. 100 reptile species and 18 amphibians have been recorded; four reptiles are endemic (*T. subtaeniatus*, *Homopholis mulleri, Platysaurus relictus* and *P. monotropis*).

Although not yet formalised, the area is proposed as a trans-frontier conservation area (TFCA). On the Botswana side is commercial farmland, mostly managed for wildlife, while on the Zimbabwe side the Tuli Circle is a protected Safari Area, two large commercial properties most of which are managed for wildlife-based tourism, and communal land. The latter are part of the CAMPFIRE programme. Much of the South African portion is under conservation management as formally or privately protected area.

The cultural sites in the area (e.g. Mapungwane), wildlife, and the scenic nature of the sandstone country, give a significant potential for tourism. Human population density is low, with liitle in the way of land use conflict, and community-based conservation programmes are operation in places. Agricultural potential (except under irrigation) is very low.

10. GAZA / KRUGER / GONAREZHOU

An extensive transfrontier area covering much of the western part of Mozambique between the Save and Limpopo rivers, the newly-gazetted Limpopo National Park in Mozambique, the northern section of the Kruger National Park in South Africa and adjacent game farms, and Gonarezhou National Park, adjacent communal lands and the Save, Chiredzi and Malilangwe conservancies in Zimbabwe. It is mostly a hot, dry and low-lying area associated with the Limpopo and Save valleys. Vegetation is principally mopane woodland, *Acacia* and *Acacia–Combretum* woodlands, with *Burkea–Terminalia* woodland on sandy soils. There are patches of rare and sometimes unique vegetation types on particular soils, such as *Brachystegia tamarinoides* woodland, *Guibourtia conjugata* thicket, *Androstachys* dry forest/thicket, riparian woodland along the larger rivers, and saline grassland and pans in the Rio Changane area. Even though it is a large area, there is a very wide range of habitats represented here.

Plant species richness is high for such an arid area and is around 1000 species. There are about 20 endemics/near-endemics, and it appears to form part of a centre of radiation, the middle Limpopo lowveld, for a group of *Acacia* species (the 'glandular' complex). Mammal diversity is high and includes good populations of elephant, white rhino, black rhino (the latter two only in the Kruger), tsessebe, nyala, cheetah, giraffe and wild dog. Lichenstein's Hartebeest is a threatened species found here. Three endemic small mammals are found. There is significant movement of large mammals across the area, especially elephant between Gonarezhou and Chicualacuala. There is a possibility of reestablishing movement between areas 9 and 10. Bird diversity is high (433 species in Kruger National Park alone) and there are three IBAs – Kruger National Park in South Africa, Limpopo/Mwenezi pans and Save/Runde junction in Zimbabwe. The former contains some globally threatened species and more than 1% of global populations of others, while the latter two contain significant numbers of range-restricted species, including the Lemon-breasted Canary. The abundant, seasonally-flooded pans of the Changane area of Mozambique are of major significance for migratory waterfowl. Two centres of high reptile/amphibian diversity are included with 50 reptile and 30 amphibian species, including 6 endemic reptiles (*Typhlosaurus richardi*, *T. fitzsimonsi*, *Nucras caesicaudata*, *Chirindia langi*, *Monopeltis decosteri*, *Xenocalamus sabiensis*) and populations of a number of relict Kalahari species (e.g. *Nucrus intertexta*) and fossorial reptiles typical of coastal alluvium (e.g. *Typhlosaurus aurantiacus*, *Zygaspis vandami*, *Typhlops fornasinii*). An endemic fish, *Nothobranchius furzeri*, is known from only a few pans in Gonarezhou.

A significant portion of the area is conserved as national park (Gonarezhou, Banhine, Zinave, Limpopo, Kruger) or as private conservancies or game farms (Malilangwe, Save, Chiredzi, farms adjacent to Kruger), while community-based wildlife management is practised in some communal lands (e.g. Sengwe, Mahenye, north of Kruger NP). However, there are numerous wildlife-human conflicts over crops and cattle, the latter owing to endemic foot-and-mouth disease and bovine tuberculosis (TB) and the necessity to keep cattle and wildlife apart. Livestock production is very significant in the area. There is a danger of increasing habitat fragmentation caused by settlement, agricultural expansion and habitat destruction (especially dry forest/thicket) by elephant. In Mozambique there is a significant threat from cutting of *Androstachys* and mopane wood for charcoal production. The future of private conservancies in Zimbabwe is very uncertain in the face of current land reforms. Tourism potential is high, and much of the area has been designated a TFCA so that land management and regulations will become harmonised and tourism planned more holistically.

11. MANICALAND — NYANGA

A transfrontier upland area comprising the highlands of Nyanga, Rukotso, Stapleford in Zimbabwe and adjacent mountains in Mozambique, along with the associated valleys and lowlands. It is more properly included in the Afromontane Ecoregion, but is mapped and described here until an ecoregion conservation programme for this is initiated. The vegetation is very varied, including fynbos-like low montane shrublands, upland grassland, high and medium altitude rainforest, high and medium altitude miombo woodlands (*Brachystegia spiciformis* and *Brachystegia utilis*), and heavily-disturbed woodlands and forest patches with affinities to the East African coastal plains. Large areas are planted to exotic conifers or wattles. The range of vegetation types is very great, reflecting the great range in altitude and soil types, and spans what is effectively three ecoregions.

Plant diversity is very high, reflecting the wide range of habitats and altitudes. There are 16 endemic/near endemic species in the Nyanga area, most of which are confined to montane grassland. Large mammal diversity is low, but there are small mammals on the boundary between the Miombo and Afromontane Ecoregions (*Lissonycteris goliath*, *Chlorotalpa arendsi*, *Myosorex 'caffer', Crocidura inyangai*, *Sylvisorex sheppardi, Aethomys silindensis*) that are endemic to these montane areas. Bird diversity is particularly high (246 species recorded from Nyanga National Park alone), with three IBAs (Nyanga mountains, Nyanga lowlands/Honde Valley, Stapleford) in Zimbabwe containing a number of range-restricted and globally threatened species. Species of particular note are the Blue Swallow, Briar Warbler, Chirinda Apalis and Swynnerton's Robin, all of which are montane grassland or forest species, not normally found in Caesalpinoid woodland. There are seasonal altitudinal movements of many bird species between miombo woodland and forest. The forest and grassland butterfly fauna is rich, particularly that associated with the ecotone between miombo and montane, with two endemics (*Deloneura sheppardi*, *Lepidochrysops chittyi*). The Nyanga uplands also contain many important prehistory sites.

There are a number of protected areas, including Nyanga National Park and State Forests in Zimbabwe. The latter, although primarily for commercial pine and wattle production, do have some intact habitat.

A significant form of land use in the upland areas is commercial timber production, and a number of valuable grassland areas were cleared for this in the 1950s. It is an important water catchment area. Tourism is also a major land use in the Nyanga/Juliasdale area of Zimbabwe, along with commercial fruit and flower cultivation. At lower altitudes, in the Honde valley and Mutasa areas, population pressures are very high in the communal lands, with grazing and subsistence crop production being the main forms of land use. The major threats in Zimbabwe are expansion of commercial timber production, invasion by exotic trees (pines, wattles) into upland grasslands, and habitat destruction from subsistence farming in the lower lying valleys. It is not clear what the status is in Mozambique.

12. MANICALAND — CHIMANIMANI

Another mostly upland transfrontier area comprising highlands of the Chimanimani and Himalaya mountains along the Zimbabwe–Mozambique border, the Chipinge Uplands, and adjacent lowlands, particularly in Mozambique. Much of it falls outside the present Miombo Ecoregion boundary. As with the previous area (11), it is more properly included under an Afromontane Ecoregion programme, but is described here to ensure its unique biological features are not overlooked or "fall between two stools".

Vegetation is very varied as would be expected from such a gradient of altitude and climate. It ranges from fynbos-like low montane shrublands, upland grassland (including unique grasslands on quartzite-derived soils), high and medium altitude rainforest, high and medium altitude miombo woodland (*Brachystegia spiciformis*, *Parinari curatellifolia*, *Pterocarpus angolensis*), and lowland rainforest with affinities to the East African coastal plains. The latter are very extensive in Mozambique, but restricted to small patches in Zimbabwe (Rusitu Valley). Chirinda Forest is the best and most extensive example of medium altitude rainforest in the region. The area spans what is effectively three ecoregions.

Total plant diversity is likely to be over 1500 species; a checklist of the non-forested parts of the Chimanimani massif shows 860 species. Nutrient-poor upland grasslands on quartzite support over 50 plant endemics. The lowland rainforests on the eastern and southern slopes are likely to support over 600 plant species; a provisional list of trees and shrubs shows 103 species. While the medium altitude Chirinda Forest and margins supports over 500 species. Mammal diversity is low with only 14 species of large and medium-sized mammals recorded from the Chimanimani massif, but 44 species are recorded from Chirinda Forest (most of them small). The only near-endemics are rodents restricted to forests and margins of the Eastern Highlands. There is a small population of forest-dwelling elephants which move through the eastern part of the area. Four IBAs are found in the Zimbabwe section – Banti Forest, Chimanimani Mountains, Haroni-Ruisitu junction and Chirinda Forest – but the range-restricted and globally threatened species present are mostly associated with forests and uplands, not Caesalpinoid woodlands. The herpetofauna is rich with 42 species around Chirinda. A rich butterfly fauna, including some endemics, is again mostly associated with forests or forest margins.

There are a number of smaller protected areas, including Chimanimani National Park, Chirinda Forest, Banti Forest and two small Botanic Reserves in Zimbabwe. The status of the forest reserves and national park is good. The Mozambican part of the Chimanimani plateau is being viewed for protection, to become part of a proposed transfrontier Chimanimani conservation area. There are also two protected forest areas in Mozambique – Maronga and Zomba.

A significant form of upland use is commercial timber production, and a number of valuable grassland areas were cleared for this in the 1950s. Much of the Chipinge Uplands and lower parts of Chimanimani in Zimbabwe is commercial farmland, especially for tea, coffee, dairy or timber. It is an important water catchment area. Tourism potential is high, particularly associated with walking in the Chimanimani Mountains. Population pressures are high in the fertile communal land of the Rusitu Valley, where remnant forest patches are being rapidly cleared. The major threat to the uplands in Zimbabwe is expansion of commercial timber production, while at medium altitude much of the vegetation has already been cleared for commercial farming, with just remaining patches on hillsides. Habitat destruction from subsistence farming or cash-cropping in the lower lying valleys is a important concern in both countries.

13. GORONGOSA / MARROMEU

An very diverse area in central Mozambique extending from Mt Gorongosa on the plateau, across the rift valley and forests of the Cheringoma plateau, to the wetlands of Marromeu, the Zambezi Delta, mangroves, dunes and coastal forests. Vegetation types (excluding those of the Afromontane portion on Mt Gorongosa) include dry miombo and *Acacia–Combretum* woodlands, *Acacia* woodlands in the valley, coastal forest with *Brachystegia spiciformis* on the Cheringoma plateau, grasslands and swamps, as well as mangroves and littoral vegetation. The area is a prime regional candidate for conservation action as it covers an enormous range of habitat ("mountain to mangrove") and straddles what is effectively three or four ecoregions within a comparatively small area.

The main protected areas, covering a major portion, are Gorongosa National Park, Marromeu Buffalo Reserve and three Game Management Areas (coutadas). The remainder is under subsistence farming, although commercial sugar plantations covered a significant area in the past, and are being rehabilitated.

Plant diversity is high owing to the altitudinal range and range of habitats, and should exceed 1500 species. There are only a few endemics or near-endemics, but a number of species of restricted distribution. Historically, large mammal diversity was high, but numbers greatly declined during and after the civil war. However, they now show signs of recovery. The main concentrations are on the rift valley floor (elephant, plains game) and on the Marromeu grasslands (buffalo, elephant). Bird diversity is also high owing to habitat diversity, with a number of localised forest species on Mt Gorongosa and Cheringoma, and important wetland bird populations in the rift valley basin and the Zambezi Delta grasslands/wetlands.

The major threats are commercial logging in the forests of Cheringoma, an influx of subsistence cultivators, poaching. The wetlands of the Zambezi Delta have been impacted upon by construction of dams upstream, changing the hydrological regime and flooding. Commercial agriculture, particularly sugar, may have a marked impact in the same area. Logging is unsustainable and only partially under control. The Gorongosa area has a number of land use conflicts resulting from the aftermath of the civil war. Extensive fires sweep across the grasslands regularly, causing much destruction. Mt Gorongosa and the Cheringoma forests are important water catchments. Tourism potential is high, and is principally wildlife-based (mostly hunting), but infrastructure is inadequate at present. The Zambezi Valley is being seen as a development hub for central Mozambique, and infrastructure (including roads and railways) is being rapidly developed or rehabilitated.

14. LUANGWA VALLEY / KASUNGU

A large, mostly low-lying area incorporating the valley of the Luangwa River in eastern Zambia, the adjacent Muchinga escarpment to the west, and part of the plateau to the east extending into the Kasungu area of central Malawi. The Luangwa is one of the least disturbed large valley systems remaining in the Miombo Ecoregion, and has not been affected by upstream dams. Although here regarded as separate from the mid-Zambezi Valley (Area 6), it is contiguous to it and has a lot of similarities biologically. The main vegetation types are mopane woodland, with patches of *Acacia-Combretum* woodland, dry forest and riverine woodland in the Luangwa Valley, and wet miombo woodland on the Muchinga escarpment and in the Kasungu area. There are also extensive grassy dambos in Kasungu.

The Luangwa Valley is very similar in plant species composition to the mid-Zambezi Valley and contains more than 1300 species, but few if any endemics. Mopane woodland is well represented, and the Muchinga escarpment supports a number of plant species of restricted distribution, including the cycad *Encephalartos schmitzii*. Dry forest and riparian woodland in good condition, both well represented here, are threatened within the ecoregion. Both the Luangwa Valley and Kasungu have a high diversity and good populations of large mammals with elephant, hippo, buffalo, lion, cheetah, leopard, wild dog, puku and sable antelope. The Muchinga escarpment acts as a biogeographical barrier between related east and southern African taxa, and thus has evolutionary significance. In the Luangwa there are two endemic mammal taxa (Thornicroft's giraffe, Cookson's wildebeest), and Lichenstein's Hartebeest is found in Kasungu National Park. There are numerous movements of large mammals between the two parts, including elephant, giraffe and puku. The area contains some endemic miombo birds (Miombo Pied Barbet, Anchitta's Sunbird), and Grey Crowned Cranes are found in Luangwa. There is an endemic tree frog *Hyperolius kachololae*. Butterfly diversity is high in Kasungu, mostly associated with the miombo woodland.

Much of the area is protected either as national park (North Luangwa, South Luangwa, Kasungu) or as game management area. Communities adjacent to the Luangwa have formed CBNRM areas based on wildlife. Both the Luangwa Valley and Kasungu are important tourism destinations, but still have much potential for development in this respect. Crop raiding and damage by mammals is a threat to surrounding agricultural communities, and poaching and unsustainable utilization of natural resources are significant threats, particularly in Malawi. Also in Malawi, the immigration of tobacco estate workers and smallholder tobacco production has led to deforestation and loss of habitat. Dambos up on the plateau in Malawi are important hydrologically, while the Luangwa river catchment is a major water source for Cabora Bassa dam in Mozambique.

15. MZIMBA / NKHOTAKOTA ESCARPMENT

A long, narrow area straddling high plateau and escarpment almost down to the western shores of Lake Malawi in central Malawi. The vegetation is mostly miombo woodland on hills and scarps comprising *Brachystegia boehmii* and similar species, and montane grasslands and forest patches up on the Viphya plateau. The latter should fall under an Afromontane Ecoregion, but are included here owing to their limited extent.

The vegetation ranges from dry miombo to montane grassland, with a moderately high plant species diversity. There is a particularly high diversity of terrestrial and epiphytic orchids. A few elephant and buffalo are present, and the area allows connectivity of large mammal movements. In addition, a number of forest birds move seasonally up and down the escarpment. Wattled Crane, a globally threatened bird species, is present. There is an endemic fish – mpasa – that breeds in the small rivers running off the escarpment.

The area is principally defined by its constituent protected areas, which are the Nkotakota Wildlife Reserve in the south, and the Nchisi, Chikangura and southern part of Viphya Forest Reserves in the north.

Threats to the area include construction of small dams on rivers running off the escarpment, plantation forestry on the Viphya Plateau in the north with invasion of alien tree species onto the plateau grasslands, shifting cultivation, poaching, and unsustainable use of natural resources including overfishing. Given the good access and scenery, there is significant potential for ecotourism.

16. UPPER SHIRE VALLEY / EASTERN ESCARPMENT

A diverse area running along the eastern escarpment flanking the southern part of Lake Malawi/Niassa in Mozambique from Lichinga southward, the upper parts of the Shire Valley in Malawi, and the adjacent highlands down to Zomba. About half the area is in Mozambique. Vegetation ranges from riparian and mopane woodland in the Shire Valley, through moist and dry miombo woodland on the escarpment to moist forest on the mountains. Some swamp vegetation is also found. Most vegetation types occur in a mosaic.

There is a very high plant species richness (over 1500 species) owing to habitat diversity, but with only a few endemics. A number of threatened plants are found. The mopane woodland in Liwonde National Park is some of the tallest in the region. Large mammal diversity is moderate, but populations are principally found in Liwonde, including black rhino, elephant, buffalo, waterbuck, sable antelope and lion. Lichenstein's hartebeest have recently been introduced. The bat fauna is rich. There is a high diversity of birds (around 450 species, 2–3 regionally threatened) including the restricted Lilian's Lovebird and Pel's Fishing Owl. There is local seasonal altitudinal movement of birds. The Shire River acts as a refuge for fish from the over-fished Lake Malombe.

Protected areas include Liwonde National Park, and the Forest Reserves of Zomba, Liwonde, Mangochi and Namizumu.

Population pressures are high, particularly in the Malawi portion, resulting in habitat destruction and encroachment of cultivation, and over-exploitation of natural resources. Poaching of wildlife and timber is a problem in places. Part of the area is under commercial tobacco estates. There is a CBNRM programme operating in the Liwonde area. The escarpment and montane woodlands are important for watershed protection by reducing flooding.

17. LOWER SHIRE VALLEY / WESTERN ESCARPMENT

A relatively small area of escarpment and valley lowland in southern Malawi east of the Shire River. It comprises dry miombo and mopane woodlands, *Acacia-Combretum* woodland, escarpment and riparian woodland, patches of dry deciduous forest/thicket and, rarely, lowland evergreen forest.

Dry deciduous and evergreen forest are rare in this part of the region, and support a number of unusual and threatened plant species. Some are believed to be endemic. The area contains the northernmost population of Nyala antelope, and has a rich bat fauna. Although elephant is not found now, it was present in the past. There are a number of restricted distribution forest birds found here, including nationally and regionally threatened species. Several endemic river fish species are found.

Protected areas include Lengwe National Park and various forest (Thambani, Matandwe) and wildlife (Mwabvi, Majete) reserves. About half the area is under some form of protection.

Threats include population pressure and encroachment from the Shire valley, including expansion of sugar plantations, smallholder irrigation schemes, unsustainable harvesting of natural resources and poaching. People often move into the area and settle to escape occasional flooding. The woodlands of the area are important as protection against flooding downslope. Pit sawing in the forest areas is a problem. There is considerable wildlife-based tourism potential.

18. COPPERBELT

A transfrontier area straddling the DRC–Zambia border in north-central Zambia and southern DRC between Lubumbashi and Ndola, adjacent to the Upemba–Kundelungu area (Area 19). It comprises the headwaters of the major Kafue river system and, in the DRC, part of the headwaters of the Luapula. Of major significance are the copper-bearing rocks of the Zambian copperbelt and Katanga. The vegetation is mostly wet miombo woodland with dambo grasslands, swamp forest, dry evergreen forest and patches of chipya (*Acacia–Combretum* woodland).

Plant diversity is also high owing to the intrusion of Congolian elements along drainage lines, in a similar fashion to the Zambezi headwaters (Area 2). Of particular note is the high number of plant endemics (c.56 species) confined to the mineral toxic soils on copper outcrops. There are many species of ground orchid, some of which are now threatened. A number of butterfly endemics are found and there is high invertebrate species diversity, again associated with swamp forest, grassland and Congolian rainforest patches.

The only protected areas are numerous small forest areas, but many are now being encroached upon. There is a bird sanctuary at Chembe.

Owing to mining, the human population is very high. There is significant competition for water and pollution of the Kafue headwaters from both mining activities and urbanisation is of concern. Deforestation due to charcoal production and fuelwood collection is a major threat. Beekeeping and fishing are also major activities. Being at the headwaters of the Kafue, the area is important for hydrological processes and as a carbon sink.

19. UPEMBA / KUNDELUNGU

A large area in Katanga Province in southern DRC incorporating Upemba and Kundelungu National Parks and the area in between. It includes lakes Kabwe and Retinue, the Lufira valley and the mountains of Kundelungu and Kibara. It is also contiguous with Lake Mweru (Area 20). Incorporating plains and plateaux, the vegetation includes wet miombo woodland, dry evergreen forest with Congolian elements, *Acacia* woodland, grassland, wetlands and riverine forest.

There is a high diversity of plants (around 4000, including 2500 on the plateau) with many endemics, including some on mineral toxic soils. There are remnants of sub-montane forest on the plateau. Mammal diversity is around 111 species, including cheetah, elephant, wild dog, lechwe, and sable antelope. Bird diversity is around 424 species, with one endemic. The area is a migratory route for palaearctic migrants and is important for waterbirds. A very rich herpetofauna (100 reptiles, 50 amphibians) includes seven endemic reptiles and six endemic frogs. Fish diversity is estimated at 140 species.

Protected areas are Upemba and Kundelungu National Parks. Their present status is not clear.

Major threats are slash-&-burn types of agriculture, extensive burning, population movements nd increase, including movement from cities to rural areas, over-fishing, poaching of wildlife, and other forms of over-exploitation of natural resources including edible orchids. There is also some commercial cattle ranching. The infrastructure and communication is very poor. The are is of major hydrological importance as it forms the catchment of the Lufira, Lualaba and part of the Luapula rivers. It is also considered to be an important carbon sink.

20. LAKE MWERU / LUAPULA

A semi-circular area extending from Lake Mweru on the eastern DRC–Zambia border, across Lake Mweru Wantipa in northern Zambia to Sumbu and the Mporokoso and Kalungwishi high plateaux. Three separate areas are combined together here into one diverse area, encompassing lacustrine, riparian, savanna and upland ecosystems. It is adjacent to Upemba–Kandelungu in the DRC (Area 19). Vegetation principally comprises wet miombo woodland and swamp grassland, with significant areas of upland dambo grassland, swamp forest, dry evergreen forest, lakeshore thicket (Lake Mweru) and patches of Itigi-like dry forest/thicket (Lake Mweru Wantipa), the latter being a particularly rare type in the region.

The high plant species diversity comes from wide habitat diversity and Congolian elements. Plant richness is high, estimated at over 2000 species. There are a number of endemic plants, especially associated with the threatened vegetation types of Itigi-like thickets, dry evergreen forest and upland dambos, and probably more remain to be discovered up on the Mporokoso plateau. Unusual mammals include Yellow-backed and Blue Duiker. An extinct taxon of lechwe (*Kobus leche robertsi*) used to be found in the area. The two lakes support large numbers of waterbirds including flamingos and miombo endemics (e.g. Swamp Flycatcher, White-winged Starling). Many of the herp endemics of Upemba are also found here, and the Congolian/West African

Slender-snouted Crocodile *Crocodylus cataphractus*. The Mweru/Luapula river area has a high fish diversity (94 species) and supports species of both Zambezian and Congolian origin. The Luapula area also has a high diversity of freshwater molluscs.

Two protected areas (Mweru Wantipa and Sumbu National Parks) are incorporated, while Lusenga Plain National Park is just outside. There are two game management areas in the Sumbu area, and a number of small Forest Reserves.

Major threats are the increasing population pressure in the area, particularly around Lake Mweru, the Luapula valley and up on the two plateaux. There has been a recent influx of refugees from the DRC into parts of the area. Traditional cultivation methods of slash-&-burn and widescale burning pose a threat to woodland and particularly dry evergreen forest patches. Lake Mweru is silting up owing to soil erosion upstream. However, there is significant tourism potential, both for wildlife and scenery. The area is considered to be important as a carbon sink, and the plateau areas are important hydrologically as source areas for the Kalungushi and other rivers that feed the lakes and similar wetland areas.

21. BANGWEULU SWAMPS

An extensive area surrounding Lake Bangweulu, the Bangweulu swamps and grasslands in north-eastern Zambia, and upstream along the Chambeshi river to the Tanzania border. It incorporates a number of wetlands and also old sand dunes to the south west. The vegetation is mostly wetland, grasslands and wet miombo woodland, with patches of dry evergreen forest.

There is moderately high plant diversity and the area forms part of the Katangan centre of diversity. There is at least one endemic shrub, *Garcinia pachyclada*. An extinct lechwe antelope *Kobus leche robertsi* was only known from Lavushi Manda, while the endemic black lechwe *K. leche smithemani* and an undescribed tsessebe (*Damaliscus*) species are only known from Bangweulu. A large fruit bat (*Eidolon helvum*) population is found in Kasanka. There are important populations and high numbers of waterbirds including the Long-tailed Flufftail and the largest populations in Zambia of Shoebill Stork and Wattled Crane. Although poorly known for reptiles and amphibians, the area supports interesting Congo forest reptile species in the swamp forests. It incorporates part of the Luapula catchment which has a high diversity of freshwater molluscs.

Three small national parks are included (Isangano, Kasanka, Lavushi Manda) along with a sizeable extent of game management area (Bangweulu, Mansa, Kafinda, Kalasamukoso, Luwingu, Chambeshi). There are a number of small Forest Reserves. The Chikuni area is a Ramsar site.

CBNRM projects are functioning here, and the area has some tourism potential. Major threats are from deforestation for charcoal production and the slash-&-burn system of agriculture. Overfishing occurs in the lake. The development corridor along the Tazara railway and main road is a potential threat as agriculture expands. The area is important for hydrological processes as it provides the headwaters of the major Luapula river system. It also acts as a carbon sink.

22. MOYOWOSI

An extensive area to the north east of Lake Tanganyika in north-western Tanzania incorporating most of the Malagarasi and Moyowosi catchments, and including the Mahale mountains to the south. The latter include much montane vegetation as well as high altitude miombo, and would be better placed under a Afromontane Ecoregion. The shoreline of Lake Tanganyika is also included, although the lake itself falls under the Great Lakes Ecoregion. Vegetation comprises wet and dry miombo woodland, grassland, very extensive wetlands and swamps, and patches of montane forest on the mountains.

Tanzania's most diverse miombo is found here, mixed with elements of the Congolian forest flora. There are over 2000 plant species with perhaps 30 endemics, although many are montane and belong more properly in the Afromontane Ecoregion. Large mammal diversity and populations are not high, but elephant are known to move through the area to the Rungwa River Game Reserve to the east. The endangered chimpanzee is found on the forest/woodland boundary on the eastern shores of Lake Tanganyika. The globally threatened birds Shoebill Stork and Wattled Crane are present. Palaearctic migrant birds move along the escarpment during migration. Four endemic reptiles occur around the lake. The Malargarasi river shows a high level of fish endemism, while Lake Tanganyika itself supports 290 fish species, of which about 90% are endemic (mostly cichlids). There is a very high butterfly species diversity owing to the range of habitat types on the mountains, with at least six endemics.

Large protected areas are the Ugalla River and Moyowosi Game Reserves, while the Mahale mountains on the lakeshore are within the Mahale Mountains National Park. There are some small forest reserves.

The area has a high human population locally, compounded by movement of refugees. Deforestation is a significant threat. Other threats include charcoal burning, unsustainable timber harvesting, mining activities and tree debarking for traditional be hives. Being an integral part of the catchment of Lake Tanganyika, it is important hydrologically. High plant growth potential means that the area is also important as a carbon sink.

23. RUKWA VALLEY

A long narrow area in south-west Tanzania along the Rukwa valley, which is considered part of the East African Rift. It includes Lake Rukwa and extends up to the Katavi plains. In some respects it may be better treated under an East African Savanna Ecoregion as there is limited Caesalpinoid woodland vegetation. The vegetation of the core area is plains and wet grasslands, which are surrounded by wet miombo woodland. The adjacent escarpments appear to have been a significant evolutionary barrier to mammals.

The plains vegetation, very similar to that of the East Africa savannas to the north, is a highly productive habitat for large mammals. The mammal biomass is said to some of the highest in East Africa, while Lake Rukwa has the highest hippo density in Tanzania. The lake also supports many Nile crocodiles. One of only two populations of puku in Tanzania are found on the wet grassland north of the lake, but the extent of this habitat has been reduced. With over 400 species of bird, the area is a wintering site and on the migratory passage for various palaearctic migrants, including the White Stork and African Pitta. It is also the northernmost extent of distribution of many southern African bird species. Long known as an important breeding ground for the red locust (it is said that locust biomass turnover exceeds that of mammals), the extent of locust breeding grounds is now greatly reduced by the rise of Lake Rukwa. It was an important tsetse area in the past.

Much of the area comprises Uwanda Game Reserve, although this is of unclear status. Owing to the presence of tsetse fly, a large part of the area has been effectively protected from human encroachment since the 1930s. To the north is the Katavi Plain Game Reserve.

Major threats include uncontrolled pastoralism, unsustainable utilization of natural resources, and an unclear protected status. Refugees have also moved into the area in recent years. There are some community-based conservation programmes in place. Tourism potentials are high, although the area is remote.

24. ITIGI THICKET

A small area of the central Tanzanian plateau between Tabora and Dodoma around the towns of Itigi and Muhanga. It lies at the headwater of the Msuguluda and Mulambi rivers on what appears to be an outcrop of Karoo sediments. The area forms part of what should be a larger conservation priority area extending southwards incorporating the Rungwa River Game Reseve and Ruaha National Park with their large populations of large mammals, especially elephant. However, as these areas comprise *Acacia–Commiphora* woodland and fall outside the Miombo Ecoregion, only the small area of unique thicket is included here. The vegetation is an almost unique and very localised thicket/dry forest type owing to an impervious hardpan in the soil.

A number of endemic plants or species of restricted distribution are found (e.g. *Bussea massaiensis*, *Baphia burtii*, *Pseudoprosopis fischeri* in the thickets, and *Nymphaea stuhlmannii* in pans). The only other area with similar vegetation is by Lake Mweru Wantipa in Zambia (Area 20). Elephants are attracted to permanent water pools in the dry season, and a number of elephant move seasonally northwest from Ruaha/Rungwe through the Itigi area towards the Ugalla River Game Reserve (Area 22). The thickets are on an important route for migratory birds. There is a high diversity of bee species. There is little published data available on the area.

No part of the Itigi thicket is protected, although the large protected areas of Ruaha National Park and Rungwa River Game Reserve lie to south.

The thicket vegetation is under severe threat from clearance and fragmentation. Local people depend on it for building material and fuelwood, and the area is surrounded by cultivation. Movement corridors for elephant and other large mammals are being increasingly blocked. There is no formal conservation plan available.

25. SELOUS / KILOMBERO

A large area in southeastern Tanzania centred on the Selous Game Reserve, including the Kibasera swamps, the Kilombero valley, and the basins of the Great Ruaha, Rufiji, Kilombero, Luwego and Matandu rivers. It is the largest protected area in Africa and a major wilderness area. Vegetation is mostly dry miombo woodland, with patches of dry forest, *Acacia* and riverine woodland, grassland and dambos.

There is high plant species diversity (2065 species listed) with around 13 endemics. The adjacent Uzungwa mountains, although outside the ecoregion, support a large number of endemics. Large mammal species diversity is high, with movement to the Niassa Game Reserve (Area 26) of elephant, buffalo and wildebeest. Black rhino and wild dog are still found. An isolated population of puku are found in the Kilombero wetlands. The endemic Iringa red colobus and Sanje mangabey monkeys are confined to upland forests on the Uzungwa mountains on the border of the ecoregion, which are better treated under the Afromontane or East African Forest Ecoregion. Over 427 bird species have been recorded, including 52 raptors. Birds endemic to the Kilombero area are the Kilombero Social Weaver, and three undescribed species of *Cisticola*. There a few Important Bird Areas and Endemic Bird Areas. There is also a rich herpetofauna with 100 reptile and 50 amphibian species, including 11 endemic reptiles and 4 amphibians in the broad Selous-Rovuma region. One endemic fish is found in the Kilombero basin. The forests and woodlands of the Uzungwa mountains support a high butterfly diversity and a number of endemics, but this belongs to the Afromontane fauna and is best regarded as part of that ecoregion.

Although the Selous Game Reserve, covering most of the area, is well protected (it is also a World Heritage Site), the Kilombero area is unprotected. In the north there is the small Mikumi National Park.

In the Kilombero area there is high population pressure and major threats from subsistence agriculture and deforestation. Livestock are grazed extensively here, and the wetlands are threatened. The planned building of a bridge over the Rufiji river would greatly improve communications with the southern part of the area, and would also increase land use pressures. Other threats include widescale burning and unsustainable extraction of valuable indigenous timbers. Tourism is an important form of land use, and there is much potential for expansion. The area is a significant carbon sink.

26. LOWER ROVUMA

An extensive transfrontier area flanking the Rovuma river comprising part of northern Niassa and Cabo Delgado provinces in northern Mozambique and Lindi district in southern Tanzania, including the town of Tunduru and much of the lower basin of the Rio Lugenda. The area forms a corridor between the Selous (Area 25) and Niassa Game Reserves, while the Rovuma river is the least disturbed river on the east coast of Africa. Around Nachingwea in Tanzania is heavily populated, so this part of the transfrontier area is not included. The mapped eastern boundary is that of the Miombo Ecoregion, but the conservation area should really be extended eastwards to the coast to include the Mueda plateau and associated coastal lowlands in Mozambique and the Rondo plateau and associated lowlands in Tanzania. Both these are exceptionally rich areas biologically, particularly for plants, but are possibly best considered under a Coastal Forest Ecoregion programme. Vegetation is dry miombo woodland bordering on East African coastal forests, both dry and evergreen. Riparian woodlands are also found.

Plant diversity is unknown but believed to be very high owing to East African coastal elements, particularly in dry forests. The adjacent area in southern Tanzania just outside the ecoregion, the Rondo plateau, has exceptionally high plant endemism in coastal forests. Mammal diversity is high although population numbers are low. Elephant are common, along with sable antelope, wild dog, zebra, wildebeest and leopard. The Rondo galago is restricted to the Rondo plateau, and there are thought to be a number of endemic small mammals towards the coast. Although there is minimal elephant movement across the Rovuma from the Niassa Game Reserve to Tanzania, the opening up of a corridor between Niassa and Selous is regarded as a major conservation priority. The area is important for intra-African migrant birds such as African Pitta and Spotted Ground Thrush. Herp diversity is not well known but is believed to be rich.

The Niassa Game Reserve is protected and surrounding areas in Mozambique are game management areas. There is a potential trans-frontier conservation agreement.

Within the Miombo Ecoregion portion, the major threats are expansion of subsistence agriculture and habitat fragmentation, widescale bushfires, unsustainable exploitation of valuable indigenous timbers, and charcoal production. Population pressures are higher in the Tanzania portion. CBNRM programmes are in place around the Niassa Reserve. Sport hunting is an important form of land use.

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Appendix 1. LIST OF ENDEMIC OR NEAR-ENDEMIC VERTEBRATE TAXA IN THE MIOMBO ECOREGION.

Name	Common names
Mammals [1,2]	
Aethomys thomasi	bush-rat
Aethomys silindensis	Selinda rat
Alcelaphus lichtensteinii	Lichtenstein's hartebeest
Amblysomus julianae	golden mole
Cercopithecus francescae	monkey
Cercopithecus moloneyi	Moloney's monkey
Chlorotalpa arendsi	Arend's golden mole
Connochaetus taurinus cooksoni	Cookson's wildebeest
Connochaetus taurinus johnstonii	Nyassa wildebeest
Crocidura ansellorum	Ansell's musk shrew
Crocidura inyangai	white-toothed shrew
Crocidura zimmeri	white-toothed shrew
Damaliscus sp.	Bangweulu tsessebe
Dendromus vernayi	Vernay's climbing mouse
Genetta angolensis	miombo genet
Gerbillurus "paeba"	hairy-footed gerbil
Giraffa cameleopardus thornicrofti	Thornicroft's giraffe
Graphiurus monardi	Monard's dormouse
Graphiurus sp.	dormouse
Hippotragus niger	sable antelope
Hippotragus niger variani	giant sable antelope
Kobus kafuensis	Kafue lechwe
Kobus leche	red lechwe
Kobus smithemani	black lechwe
Kobus vardoni	puku
Kobus sp.	Kilomberu puku
Lemniscomys roseveari	zebra mouse
Lissonycteris goliath	Harrison's fruit bat
Malacomys australis	Ansell's long-footed rat
Myosorex caffer	mouse shrew
Paraxerus cepapi	Smith's bush squirrel
Raphicerus sharpei	Sharpe's grysbok
Rhinolophus sakejensis	Sakeji horseshoe bat
Sylvisorex sheppardii	climbing shrew
Tatera brantsi	gerbil

Birds

Agapornis lilianae	Lilian's Lovebird
Agapornis nigrigenis	Black-cheeked Lovebird
Anthreptes longuemarei	Violet-backed Sunbird
Anthreptes anchietae	Red-and-blue (Anchieta's) Sunbird
Anthus nyassae	Wood Pipit
Apalis alticola/cinerea	Brown-headed Apalis
Batis margaritae	Margaret's Batis
Calamonastes undosus/simplex (S)	Stierling's Barred Warbler
Calamonastes undosus (N)	Miombo Wren Warbler
Centropus cupreicaudus	Coppery-tailed Coucal
Cercotrichas barbata	Miombo Beared Scrub Robin
Cisticola dambo	Dambo Cisticola
Cisticola pipiens	Chirping Cisticola
Cisticola melanurus	Black-tailed Cisticola
Coracias spatulata	Raquet-tailed Roller
Dendropicos stierlingi	Stierling's Woodpecker
Egretta vinaceigula	Slaty Egret
Elminia albicaudata	White-tailed Blue Flycatcher
Emberiza cabanisi	Cabanis's Bunting
Eremomela atricollis	Black-necked Eremomela
Erythrocercus livingstonei	Livingstone's Flycatcher
Estrilda thomensis	Cinderella Waxbill
Estrilda nigriloris	Black-lored Waxbill
Francolinus finschi	Finsch's Francolin
Hirundo nigrorufa	Black-and-Rufous Swallow
Hyliota australis	Southern Hyliota
Hypargos niveoguttatus	Red-throated Twinspot
Lagonosticta nitidula	Brown Firefinch
Lamprotornis acuticaudus	Sharp-tailed Starling
Lamprotornis mevesii	Southern Long-tailed Starling
Lanius souzae	Souza's Shrike
Lybius chaplini	Chaplin's Barbet
Macronyx fuellebornii	Fuelleborn's Longclaw
Macronyx grimwoodi	Grimwood's Longclaw
Malaconotus monteiri	Monteiro's Bushshrike
Merops boehmii	Boehm's Bee-eater
Mirafra angolensis	Angola Lark

Monticola angolensis	Miombo Rock Thrush
Muscicapa boehmi	Boehm's Flycatcher
Myrmecocichla arnotti	White-headed Black (Arnot's) Chat
Myrmecocichla thollonii	Congo Moor Chat
Nectarinia bocagei	Bocage's Sunbird
Nectarinia oustaleti	Oustalet's White-bellied Sunbird
Nectarinia manoensis	Miombo double-collared Sunbird
Nectarinia shelleyi	Shelley's Sunbird
Neocichla gutteralis	White-winged Starling
Neolestes torquatus	Black-collared Bulbul Shrike
Ortygospiza locustella	Locust Finch
Parus rufiventris	Rufous-bellied Tit
Parus pallidiventris	Cinnamon-breasted Tit
Parus giseiventris	Miombo Grey Tit
Phylloscopus laurae	Laura's Woodland Warbler
Pinacorys nigricans	Dusky Lark
Pinarornis plumosus	Boulder Chat
Plocepasser rufoscapulatus	Chestnut-mantled Sparrow-weaver
Ploceus bertrandi	Bertram's Weaver
Ploceus ruweti	Ruwet's Masked Weavet
Ploceus olivaceiceps	Olive-headed Weaver
Ploceus katangae	Katanga Masked Weaver
Ploceus angolensis	Bar-winged Weaver
Ploceus reichardi	Lake Lufira Weaver
Ploceus burnieri	Kilombero Weaver
Ploceus xanthopterus	Brown-throated Golden Weaver
Ploceus temporalis	Bocage's Weaver
Pyrenestes minor	Lesser Seedcracker
Serinus mennelli	Black-eared (Mennel's) Seedeater
Serinus reichardi	Reichard's Seedeater
Stactolaema anchietae	Anchieta's Barbet
Stactolaema whytii	Whyte's Barbet
Sylvietta ruficapilla	Red-capped Crombec
Tockus pallidirostris	Pale-billed Hornbill
Tockus bradfieldi	Bradfield's Hornbill
Tricholaema frontata	Miombo Pied Barbet
Turaco (persa) livingstonei	Livingstone's Loerie
Turdoides hartlaubii	Hartaub's Babbler

Turdoides melanops	Black-faced Babbler
Vidua obtusa	Broadtailed Paradise Whydah
Vidua codringtoni	Peter's Twinspot Indigobird

Reptiles [4]

Afroedura loveridgei	Loveridge's Flat-gecko
Afroedura transvaalica	Limpopo Flat-gecko
Afrogecko ansorgii	Ansorge's Leaf-toed Gecko
Agama kirkii	Kirk's Rock Agama
Amblyodipsas katangensis	Katanga Purple-glossed Snake
Amblyodipsas ventrimaculata	Kalahari Purple-glossed Snake
Aparallactus moeruensis	Mweru Centipede-eater
Atheris katangensis	Katanga Bush Viper
Atheris rungweensis	Rungwe Bush Viper
Bitis heraldica	Bocage's Montane Viper
Causus bilineatus	Lined Night-adder
Chamaeleo anchietae	Anchieta's Chameleon
Chilorhinophis gerardi	Gerard's Black & Yellow Burrowing Snake
Chirindia langi	Lang's Round-snouted Worm Lizard
Cordylus angolensis	Angola Girdled Lizard
Cordylus depressus	Soutpansberg Girdled Lizard
Cordylus mossambicus	Gorongosa Girdled Lizard
Cordylus regius	Regal Girdled Lizard
Cordylus vandami	Van Dam's Girdled Lizard
Dalophia angolensis	Angolan Pestle-tailed Worm-lizard
Dalophia ellenbergeri	Barotse Pestle-tailed Worm-lizard
Dalophia longicauda	Long-tail Pestle-tailed Worm-lizard
Dalophia luluae	Sandoa Pestle-tailed Worm-lizard
Gerrhosaurus bulsi	Buls' Plated Lizard
Hemidactylus tasmani	Tasman's Rock Gecko
Homopholis mulleri	Muller's Velvet Gecko
Ichnotropis bivittata	Angolan Rough-scaled Lizard
Ichnotropis grandiceps	Caprivi Rough-scaled Lizard
Ichnotropis tanganicana	Lake Tanganyika Rough-scaled Lizard
Latastia johnstoni	Johnston's Scrub Lizard
Leptosiaphos dewittei	De Witte's Five-toed Skink
Limnophis bicolor	Angolan Striped Water Snake
Loveridgea phylofiniens	Udjiji Round-snouted Worm Lizard
Lycodonomorphus bicolor	Lake Tanganyika Water Snake
Lycodonomorphus mlanjensis	Mulanje Water Snake
Lygodactylus angolensis	Angolan Dwarf Gecko

Lygodactylus chobiensis	Chobe Dwarf Gecko
Lygodactylus stevensoni	Stevenson's Dwarf Gecko
Lygodactylus heeneni	Heenen's Dwarf Gecko
Mabuya angolensis	Angolan Skink
Mabuya bayonii	Bayon's Skink
Mabuya ivensii	Ivens' Skink
Mabuya lacertiformis	Bronze Rock Skink
Monopeltis adercae	Lualaba Spade-snouted Worm-lizard
Monopeltis perplexus	Perplexing Spade-snouted Worm-lizard
Monopeltis remaclei	Witte's Spade-snouted Worm-lizard
Monopeltis rhodesiana	Zimbabwean Spade-snouted Worm-lizard
Monopeltis scalper	Scalpel Spade-snouted Worm-lizard
Monopeltis zambezensis	Zambezi Spade-snouted Worm-lizard
Natriciteres bipostocularis	Southwestern Marsh Snake
Pachydactylus oshaughnessyi	Oshaughnessy's Thick-toed Gecko
Pachydactylus tetensis	Tete Thick-toed Gecko
Pachydactylus tigrinus	Tiger Thick-toed Gecko
Panaspis megalurus	Blue-tailed Snake-eyed Skink
Panaspis seydeli	Katanga Snake-eyed Skink
Pelusios nanus	Dwarf Hinged Terrapin
Pelusios upembae	Upemba Hinged Terrapin
Philothamnus ornatus	Ornate Green Snake
Platysaurus imperator	Imperial Flat-lizard
Platysaurus intermedius	Matschie's Flat-lizard
Platysaurus maculatus	Spotted Flat-lizard
Platysaurus mitchelli	Mulanje Flat-lizard
Platysaurus monotropis	Orange Flat-lizard
Platysaurus nyasae	Shire Flat-lizard
Platysaurus parvus	Blouberg Flat-lizard
Platysaurus pungweensis	Pungwe Flat Lizard
Platysaurus relictus	Soutpansberg Flat-lizard
Platysaurus rhodesianus	Zimbabwean Flat-lizard
Platysaurus subniger	Mashona Flat-lizard
Platysaurus torquatus	Striped Flat-lizard
Psammophis ansorgii	Ansorge's Whip Snake
Psammophis sp. nov.	Zambian Whip Snake
Rhinotyphlops anomalus	Anomalous Beaked Blind-snake
Rhinotyphlops gracilis	Gracile Beaked Blind-snake
Rhinotyphlops kibarae	Upemba Beaked Blind-snake
Scelotes limpopoensis	Limpopo Dwarf Burrowing Skink
Tetradactylus ellenbergeri	Ellenberger's Whip-lizard
Typhlacontias gracilis	Barotse Burrowing Skink

Typhlosaurus jappi	Barotse Blind Legless Skink
Typhlops schmidti	Schmidt's Blind-snake
Xenocalamus sabiensis	Save Quill-snouted Snake
Zygaspis kafuensis	Kafue Round-snouted Worm-lizard
Zygaspis nigra	Black Round-snouted Worm-lizard

Amphibians [4]

Afrixalus wittei	De Witte's Leaf-folding Frog
Breviceps poweri	Zambian Rain Frog
Bufo fuliginatus	Katanga Toad
Bufo melanopleura	Upemba Toad
Bufo reesi	Rees' Toad
Bufo urunguensis	Urungu Toad
Hemisus sp. nov.	Barotse Shovelsnout Frog
Hemisus wittei	Upemba Shovelsnout Frog
Hildebrandtia ornatissima	Angola Ornate Frog
Hylarana darlingi	Golden-backed Frog
Hylarana lemairii	Lemaire's Forest Frog
Hyperolius bocagei	Bocage's Reed Frog
Hyperolius kachololae	Kachola Reed Frog
Hyperolius kibarae	Upemba Reed Frog
Hyperolius obscurus	Kasai Reed Frog
Hyperolius quinquevittatus	Five-lined Reed Frog
Hyperolius reesi	Kilombero Reed Frog
Hyperolius vilhenai	Luita River Reed Frog
Hyperolius viridis	Green Reed Frog
Kassina kuvangensis	Kuvangu Running-frog
Kassinula wittei	Witte's Running-frog
Leptopelis fiziensis	Fizi Forest Treefrog
Leptopelis lebeaui	Nyonga Forest Treefrog
Leptopelis parvus	Upemba Forest Treefrog
Phrynobatrachus anotis	Lusinga Puddle Frog
Phrynobatrachus parvulus	Least Puddle Frog
Phrynobatrachus rungwensis	Rungwe Puddle Frog
Phrynobatrachus stewartae	Stewart's Puddle Frog
Ptychadena ansorgii	Ansorge's Ridged-frog
Ptychadena bunoderma	Tuberculate Ridged-frog
Ptychadena keilingi	Keiling's Ridged-frog
Ptychadena mapacha	Mapacha Ridged-frog
Ptychadena obscura	Obscure Ridged-frog
Ptychadena upembae	Upemba Ridged-frog
Spelaeophryne methneri	Methner's Cave Frog

Stephopaedes anotis	Chirinda Earless Toad

Freshwater fish [5]

Aethiomastecembelus signatus
Bagrus meridionalis
Barbus arcislongae
Barbus argenteus
Barbus bellcrossi
Barbus breviceps
Barbus choloensis
Barbus dorsolineatus
Barbus eurystomus
Barbus johnstonii
Barbus litamba
Barbus manicensis
Barbus owenae
Bathyclarias spp.
Chetia welwitschi
Chiloglanis emarginatus
Engraulicypris sardella
Hydrocynus tanzaniae
Hypsopanchax jubbi
Kneria maydelli
Labeo ansorgii
Labeo mesops
Labeo ruddi
Labeo simpsoni
Labeo worthingtonii
Marcusenius nyasensis
Nothobranchius furzeri
Nothobranchius kafuensis
Nothobranchius sp.
Nyassachromis spp.
Opsaridium microcephalum
Opsaridium microlepis
Opsaridium tweddlorum
Oreochromis shiranus
Orthochromis machadoi
Paramormyrops jacksoni
Sargochromis coulteri
Sargochromis gracilis

Schwetzochromis machadoi
Synodontis njassae
Thoracochromis albolabris
Thoracochromis buysi
Tylochromis bangwelensis
Varicorhinus pungweensis

NB. In many cases an evolutionary species concept is used; hence subspecies and varieties may have been raised to specific status.

Sources:
1. WWF Conservation Science Division database, Oct 2001 (original WWF ecoregions)
2. Fenton Cotterill, pers. comm. (Oct 2001)
3. Peter Frost, pers. comm. (Dec 2001)
4. Don Broadley, pers. comm. (Nov 2001)
5. Brian Marshall (2000) and pers. comm. (Nov 2001); excludes species from Great Lakes.

Appendix 2. MIOMBO ECOREGION HABITATS

The ecoregion planning process identifies areas of importance based on species diversity and endemism, as well as ecological or evolutionary processes. Representation of habitats across the area is not explicitly covered.

Recognising this, the plant/vegetation group at the October workshop attempted to identify many of the best examples of habitats across the ecoregion, also trying to ensure representation of all major types. This is presented here and in Figure 7 below, but must be considered very preliminary.

A total of 29 areas were identified that are considered to be important habitats, and also give good representation of the major types across the region. These are based on the important plant areas, and were enlarged to cover all vegetation types and Afromontane forests and grasslands.

Code	**Area**
Ha1	Selous Game Reserve
Ha2	Lower Rovuma & inselbergs
Ha3	Mahale / Karobwa hills
Ha4	Kolwezi / Lumbumbashi
Ha5	Itigi thicket
Ha6	Great Dyke (N & S)
Ha7	Limpopo valley / G-K-G
Ha8	Zambezi headwaters
Ha9	Barotseland
Ha10	Huambo / Huila / Benguela / Bié plateau & highlands
Ha11	Luangwa valley
Ha12	Middle Zambezi valley
Ha13	Shire valley & highlands
Ha14	Mt Mulanje
Ha15	Gorongosa / Marromeu
Ha16	Nyanga mountains
Ha17	Chimanimani mountains
Ha18	Felixburg
Ha19	Nata river
Ha20	*Baikiaea* woodlands
Ha21	Kafue Flats

Ha22	Nyika plateau
Ha23	Misuku hills / Livingstone mountains
Ha24	Bangweulu swamps
Ha25	Lake Mweru Wantipa
Ha26	Upemba National Park
Ha27	Matobo hills
Ha28	Cuando-Cubango plains
Ha29	Lower Cunene

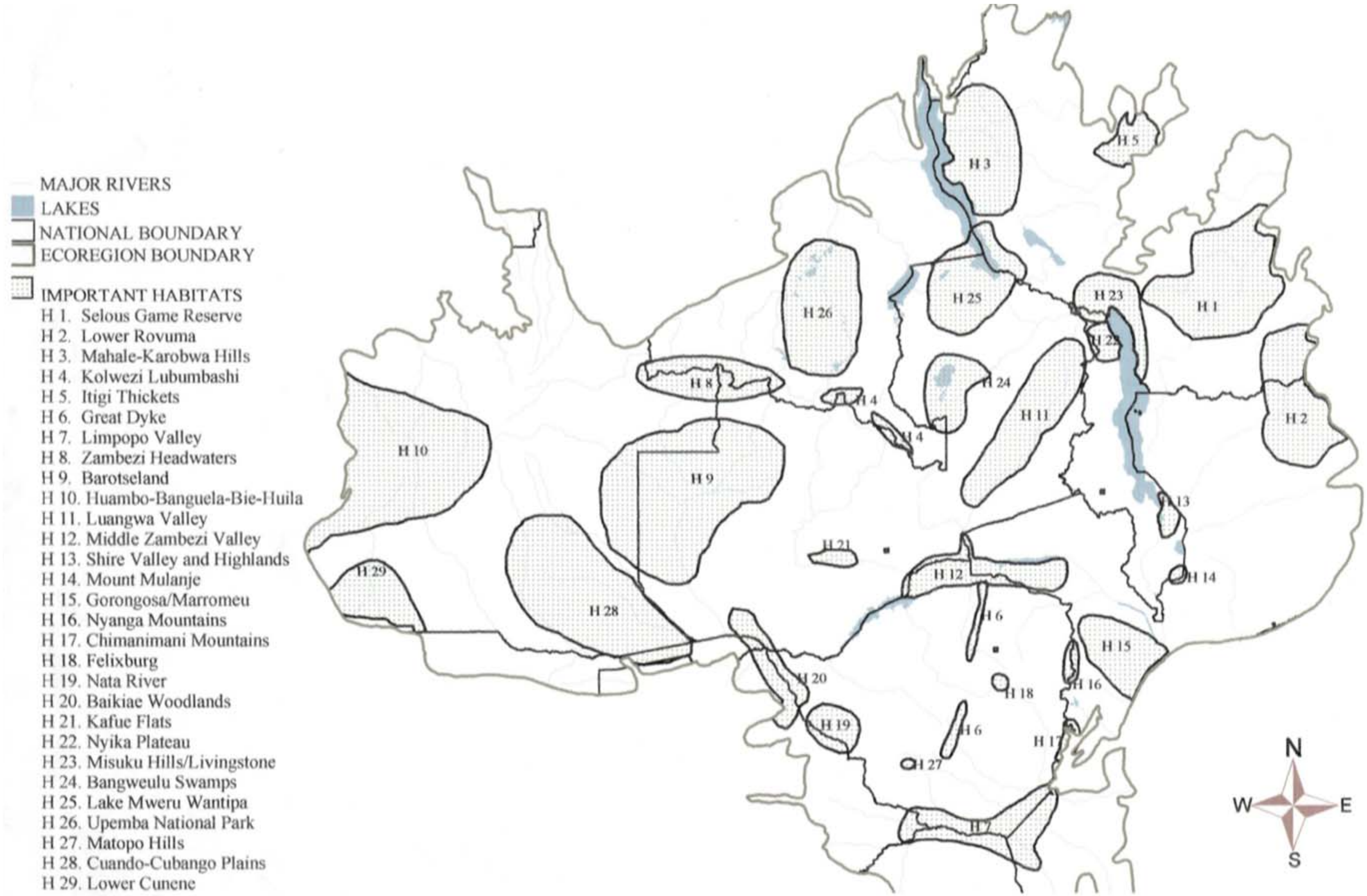

Figure 7. Miombo Ecoregion – areas of significance for habitat conservation