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Miombo Woodlands Research Towards the Sustainable Use of Ecosystem Services in Southern Africa

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Additional information is available at the end of the chapter

1. Introduction

The Miombo woodlands are the most extensive warm dry forest type in southern Africa [1], covering ca. 2.7 million km^2 across seven countries: Tanzania and the Democratic Republic of Congo (DRC) in the north, Angola and Zambia in the east, and Malawi, Zimbabwe and Mozambique in the south [2-4] (Figure 1). It is one of the most important ecosystems in the world, playing an important role at the social, economic and environmental levels. Being an important center of plant biodiversity Miombo is a key provider of goods and services, supporting the livelihoods of more than 65 million of people in the region [4]. The woodlands are also very important to the national economies as they provide timber for exportation. From the environmental point of view Miombo is determinant to energy, carbon and water balance [3,5].

The ecological dynamics of Miombo is strongly influenced by their woody component, particularly by large trees, which play a key role in ecosystem function, primarily in nutrient cycling, accounting for a great deal of the carbon pool. This component is in turn influenced by a combination of climate, disturbances [e.g. drought, fire, grazing and herbivory primarily by elephants (*Loxodonta africana* Blumenbach)] and human activities [6-7]. Growing population in the region over the last 20-25 years has resulted in increased woodland degradation and deforestation. Slash and burn agriculture and charcoal production are the major causes of forest loss and degradation in the Miombo Ecoregion [8-10]. Additionally, the region is experiencing several major investments in mining, commercial agriculture and infrastructures, which have further increased the pressure on the woodlands. In Zambia for example, where
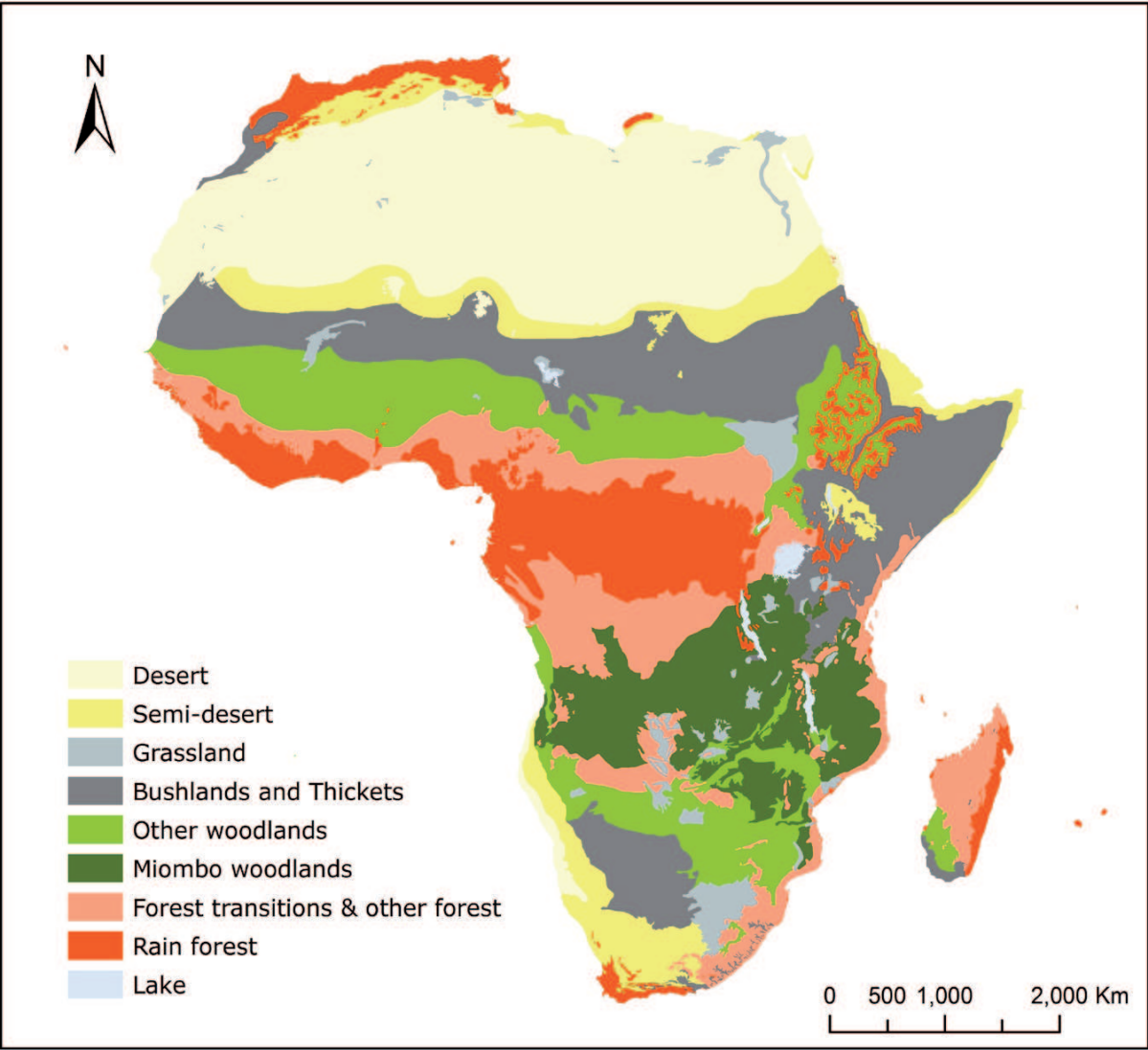
Figure 1. Map of African vegetation, showing the Miombo woodlands in dark green (Source: White, 1983).

there is large-scale mining for copper, the mining sector has greatly contributed to forest cover and biomass losses. Often, huge tracts of land are cleared to provide space for mining infrastructures; at Kalumbila Concession, Solwezi alone, infrastructure development resulted in the loss of more than 7,000 hectares of land [11]. This is often followed by an increased demand for construction timber, creating further pressure on forests.

Changes in the global climatic pattern, *e.g.* 5-15% predicted reduction in precipitation for southern Africa [12], constitute another major threat across the various global ecosystems. In the Miombo Woodlands, they are mainly associated with more extreme wet and dry seasons, *i.e.* drier interior regions, wetter coastal regions, as well as extreme temperatures, which may change disturbances regimes (fire, shifting cultivation, amongst others) and thus the prevailing biodiversity status. According to [13], the combined effect of climate change and disturbances may cause the loss of ca. 40% of the woodlands by the middle of the century. There is an increased concern that the loss of mature trees in landscapes may result in the transformation of the woodlands into scrub or grasslands. This may impose changes in biodiversity and

biomass with associated modifications on the pattern of goods and services offered by this ecosystem.

It is widely recognized that Miombo Woodlands have great potential to provide financial resources through Carbon-based Payment for Ecosystem Services (PES) [14], but their function as dynamic C-pools in biogeochemical cycles is largely unknown [15]. In this context, understanding biodiversity and carbon variations under different land use scenarios as well as the rates and the extent to which Miombo recover from disturbances has important implications in the emerging C-based PES schemes [16], which are taking center-stage in the United Nations Framework Convention on Climate Change (UNFCCC) through mechanisms such as Reducing Emission from Deforestation and Forest Degradation (REDD+). On the other hand, such assessments will be crucial for future land use decisions to ensure optimal land use benefits, hence ensuring forest conservation and sustainable management [15].

Under the scenario described above, current research efforts in the region aim at understanding the ecology of Miombo including its biodiversity, biomass production and carbon sequestration, as well as the role of disturbances and its socio-economic relevance. In this chapter we summarize the existing information on the dynamics of biodiversity and biomass /carbon), in order to identify research gaps and needs. It is our intention to contribute towards a research agenda for the Miombo Woodlands, which is being developed under the context of the Miombo Network of Southern Africa, an alliance of scientists for informed research to decision making in the region.

2. Biodiversity dynamics

Miombo has an estimated diversity of 8,500 plant species, of which ca. 54% are endemic. Together with Mopane, it is amongst the five high biodiversity wilderness areas in the world whose conservation should be prioritized because of their irreplaceability in terms of species endemism [17-18]. The woodlands are characterized by the overwhelming dominance of *Brachystegia* (*Miombo* in Swahili), *Julbernardia* and *Isoberlinia* tree species belonging to the Fabaceae (legume) family [19-20], associated with a variety of other woody plants, such as *Pseudolachnostylis maprouneifolia* Pax., *Burkea africana* Hook and *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon. In mature Miombo these species comprise an upper canopy layer made of 10-20 m high trees and a scattered layer of sub-canopy trees. The understorey is discontinuous and composed of broadleaved shrubs of the genera *Eriosema, Sphenostylis, Kotschya, Dolichos* and *Indigofera*, among others, and suppressed saplings of canopy trees. A sparse but continuous herbaceous layer of grasses, forbs and sedges composed of *Hyparrhenia, Andropogon, Loudetia, Digitaria* and *Eragrostis* dominate the ground-layer [2,21]. Miombo is usually referred as a homogenous ecosystem, but differences in species composition, diversity and structure occur at a local scale [22]. The origin of these differences is unclear but, geomorphic evolution of the landscape [23], soil moisture and nutrients [24], land uses changes and other anthropogenic disturbances [25] have all been indicated. Figure 2 illustrates Miombo structure and composition and fire occurrence.

Figure 2. Illustrative exemple of the Miombo Woodlands. (A) Diversity of tree species; (B) Close up pf *Brachystegia bohemii*; (C) Regrowing area; (D) Recently burned area. Credits to Isabel Moura, Tropical Research Institute, Portugal (A, B) and Ivete Maquia, Biotechnology Center, Eduardo Mondlane University (C, D)

Only a few Miombo biodiversity studies have been recently published and most of them were focused either on a limited number of tree species and/or on specific geographical locations. Hence, the information on the conservation status of Miombo plant species is scarce. For example, based on the existing national surveys, the number of threatened plant species is difficult, if not impossible, to estimate, but the Sudan-Zambezian zone, to which the Woodlands belong, is reported to have the highest values of threatened species [18]. Since the conservation status of a particular species is a good indicator of the impact of threats and its capacity to provide goods and services [26], site-specific studies confined to one or to a small group of species are of utmost importance to upgrade the existing information and thus help future planning and management programs.

The establishment and management of fully protected areas such as National Parks are often assumed to be the best strategy for conserving species diversity and maintain forest composition and structure. To evaluate this assertion, Banda and co-authors [27] conducted a study in western Tanzania in areas with four different levels of protection: a National Park (high protection level), a Game Controlled Area (with tourist hunting of big game animals), a Forest

Reserve (with selective harvest of trees), and an Open Area (unrestricted access to forest resources). The authors observed that the forest structure was quite similar in the four sites and that species richness was significantly higher in the Game Controlled Area and Forest Reserve than in the other areas. More recently, Giliba and collaborators [22] assessed species richness, diversity, dominance and exploitation in Bereku Forest Reserve, northern Tanzania, concluding that the use of Miombo products and services by the surrounding communities does not compromise the stability of the woodlands, which are fairly stocked with high tree and shrub species diversity. These studies suggest that National Parks do not always host the greatest diversity of trees or unique species. This may imply that a suite of different types of protection strategies may be the key for conservation in African dry tropical forests [27].

The effect of environmental factors, particularly soil and disturbance history, on tree diversity and size structure was analysed by [19] in and around the Ihombwe village, Kilosa District,Tanzania where shifting cultivation is practiced. The authors observed that there was a considerably high capacity for tree species regeneration, partly due to the relatively isolated position of the village and also due to the fact that local communities recognize the importance of the sustainable ecosystem use. However, fires were pointed as the main driver of species composition change as they tend to support the proliferation of fire tolerant species, such as *P. maprouneifolia*, *Pterocarpus angolensis* DC and *D. condylocarpon* at the expense of dominant Miombo species. Similarly, [27] observed the dominance of *Terminalia sericea* Burch. ex DC., *Combretum adenogonium* Steud. ex A.Rich., and *C. colinum* Fresen. in dry Miombo of the Katavi-Rukwa ecosystem of western Tanzania due to frequent burning. Also Williams and co-authors [28], working on the effects of slash-and-burn agriculture in the Nhambita community, Sofala Province, Mozambique, observed that in abandoned (regrowing) sites, defining Miombo species were replaced by secondary dominant trees. However, the biodiversity of woody species (i.e. Shannon index and species richness) in older abandonments (>10 years old) and intact woodlands were similar. In general tree biodiversity has not been degraded by the slash-and-burn disturbance, but the time-scale of recovery of defining Miombo species was unclear. In Zambia [29-31] have also suggested that though Miombo systems recover relatively fast in terms of species diversity, species composition takes longer to recuperate. In another study in Mozambique, [32] observed that fire and herbivory by elephants are the main drivers of ecosystem structure and composition. For example, places with high fire frequency and elephant density were dominated by fire-resistant species such as *T. stenostachya*, *Combretum* spp. and *D. condylocarpon*. Similar results were obtained by [33] in the Miombo Woodlands of north-western Zimbabwe, where elephants and fires reduced the proportions of large trees, tree heights, stem basal area and densities of all trees. Besides that, tree species frequencies dropped 28–89.6% and the most visible floristic alteration was the replacement of the typical *Brachystegia boehmii* Taub. by *P. maprouneifolia* and Combretaceae species. The results are in line with those from [19,27-28] and are corroborated by the prediction model developed by [34] regarding the impact of elephants and fires on the structure of semi-arid Miombo Woodlands of north-western Zimbabwe. The author hypothesized that elephants alone at a density of 0.27 km^{-2} would convert the woodland into coppice in 120 years due to massive declines of large trees; the same result would be achieved in 10 years if elephant density

increased to 2 km^{-2}; the pattern would remain similar if simultaneous fire occurred once every 4.7 years with elephants at 0.27 km^{-2}. Thus, it was predicted that elephants alone can degrade and maintain semi-arid Miombo Woodlands into coppice, largely due to their damaging impacts on mature canopy trees. Fire may also speed up the process by suppression of an already low recruitment. However, this driver alone had less influence on the woodland structure than elephants because of low fuel loads due to heavy grazing and low grass production as a result of low rainfall and inherently poor soils in the area.

Another important aspect in understanding the biodiversity dynamics in the Miombo Woodlands and in assisting conservation programs, is the application of molecular markers (MM). MM are essential tools to analyse population structure and genetic diversity as well as to identify particular traits (including genotypes and genes) associated with outstanding performances and resilience to extreme environments (*e.g.* fire, drought, high temperatures) [35-37]. The use of MM to understand the dynamics and potentialities of Miombo species is still incipient and only two studies have been published. The first reported on the use of Amplified Fragment Length Polymorphisms (AFLP) to assess the genetic diversity of natural populations of *Uapaca kirkiana* Muel. Arg. from three geographical regions of Malawi, in relation to deforestation, fragmentation and wildfires [38]. AFLP markers revealed moderate differentiation among the studied populations, but very high variation among individuals within populations. The second study was based on the use Inter Simple Sequence Repeat (ISSR) markers to assess genetic diversity in *B. boehmii* and *B. africana* across a fire gradient in the Niassa National Reserve (NNR) [39]. Although fire differentially affected the biodiversity in each species, in general, the overall genetic diversity was high and their survival did not seem to be compromised by the frequency of fires, agreeing with the fact that NNR is one of the least disturbed areas of deciduous Miombo. The results point also to a link between fire-tolerance and genetic diversity, as judged by the higher diversity levels observed in *B. africana* (fire-tolerant) in comparison to *B. boehmii* (fire-sensitive). Furthermore, *B. boehmii* presented an evolutionary response to fire, i.e. the levels of diversity were lower in frequent fire prone areas than in areas of low fire frequency, a phenomena attributed to the pyrodiversity-like effect [40]. In both papers, the authors emphasize the need for more intensive genetic studies spanning other populations of these and other important tree species to produce a wider picture of the levels of distribution of genetic diversity across the Miombo Ecoregion and its relation to major threats.

In conclusion, the available literature generally suggests that biodiversity in the miombo woodlands is shaped by disturbances, including anthropogenic actions, and to some extent may be compromised by the ongoing pressures. Despite the risks to which the woodlands are exposed, the species diversity and the levels of genetic diversity are considerably high. This seems to be particularly associated with the apparent resiliency of Miombo to various disturbances. However, there are evidences that typical species not always recover and in some cases may be replaced by secondary species. As a consequence, the range and type of goods and services provided by the woodlands may be altered. This calls for the implementation of management strategies that are appropriate for conserving biodiversity of Miombo.

2.1. Biomass and carbon dynamics

Estimations of biomass and carbon stocks are an essential step in accounting for ecosystem goods and services particularly when considering land use options and strategies to promote carbon sequestration. This is relevant for implementing carbon credit market mechanisms such as REDD+, which seeks to mitigate climate change through enhanced CO_2 storage in terrestrial ecosystems.

Biomass and carbon stocks have a pronounced variation across the Miombo Ecoregion. This has been mainly associated to: i) soil fertility and plant nutrition; ii) fires and herbivory; and iii) age and status of the woodland. Woody biomass was observed to range from 1.5 Mg ha^{-1} (3-6 years old coppice) to 144 Mg ha^{-1} (mature wet Miombo) [9,41-45]. Dry Miombo ranges between 53-55 Mg ha^{-1} [45-48]. It is confirmed that wood and soil compartments are the most important of these stocks [48-49], but grass, litter and root may contribute significantly to carbon sequestration. Table 1 presents comparative results of carbon stock density in different compartments across different sites.

Ecosystem compartment	Carbon Stock Density (Mg C ha^{-1})	Localization	Reference
Soil	57.90	Gorongosa, Mozambique	[28]
	34.72 ± 17.93	Niassa Reserve, Mozambique	[48]
	31.04	Dombe, Manica, Mozambique	[47]
Trees	19.00 ± 8.00	Gorongosa, Mozambique	[28]
	13.17 - 32.10	Beira Corridor, Mozambique	[50]
	20.88	Niassa Reserve, Mozambique	Sitoe, Unpublished data
	26.48	Dombe, Manica, Mozambique	[47]
	29.88 ± 13.07	Niassa Reserve, Mozambique	[48]
Grasses	1.2	Niassa Reserve, Mozambique	Sitoe, Unpublished data
	0.65	Dombe, Manica, Mozambique	[47]
	030 ± 0.89	Niassa Reserve, Mozambique	[48]
Litter	0.80	Niassa Reserve, Mozambique	Sitoe, Unpublished data
	3.00	Dombe, Manica, Mozambique	[47]
	0.06 ± 0.03	Niassa Reserve, Mozambique	[48]
Dead Trees	0.06 ± 0.19	Niassa Reserve, Mozambique	[48]
Herbaceous	0.02 ± 0.01	Niassa Reserve, Mozambique	[48]
	0.55 ± 0.02	Eastern Arc Mountains, Tanzania	[49]
Total carbon	10.13-79.69	Niassa Reserve, Mozambique	[48]
	13 - 30	Eastern Arc Mountains, Tanzania	[48]

Table 1. Comparative results of Carbon Stock Density across the Miombo Ecoregion. Source: Adapted from [48].

The dynamics of Miombo is in general influenced by its tree component given its dominance. Wood vegetation is in turn affected by environmental and disturbance factors [1]. Fire is particularly an important factor in Miombo as its behavior, timing, intensity and frequency vary greatly across the ecosystem, thus affecting vegetation structure and biomass differently. Frequent late dry season fires can transform woodland into open tall grass savanna with isolated fire-tolerant canopy trees and scattered understorey trees and shrubs [52] thereby reducing woody biomass. The impact of fires on biomass and carbon stocks has been addressed in a few countries. [53] in Zimbabwe, [54] and [31] in Zambia, and [46] and [55] in Mozambique have observed that fire protected sites had more woody biomass than frequently burned sites. [55] also noted that annual fire suppressed woody biomass development (up to 38 Mgha^{-1} in the studied area of central Mozambique) while low intensity fires at lower frequencies promoted biomass accumulation. Many studies have reported that once trees reach a certain height, they are less susceptible to fire [54 and references therein]. However, in his 22-year period study in Zambia, [31] found that large and tall trees were just as susceptible to fire as small trees, but their death was gradual and occurred over longer periods of time. In this area, fire alone was responsible for more than 25% of the observed biomass losses. The author concluded that avoided forest degradation at the study sites would have increased standing woody biomass up to 4.0 t ha^{-1} year^{-1} over the 22-year period. Recently, [45] found that carbon storage in the tree-dominated ecosystems of the Tanzanian Eastern Arc Mountains has decreased at a mean rate of 1.47 Mg C ha^{-1} yr^{-1} (ca. 2% of the stocks of carbon per year) due to 74% forest area loss driven by 5-fold increase in cropland area.

The interactive effect of fire and herbivory by elephants is quite interesting in Miombo. In general, elephants uproot, de-branch and/or debark large trees, increasing fuel-load in the forest ground due to intensified light intensity. Higher fuel loads result in frequent and fierce fires that influence the woodland. [42] and [56] have studied the effect of elephants in Sengwa National Park, Zimbabwe. The study compared areas inside the National Park (high elephant density and fire occurrence) and outside the National Park (low elephant density and fire occurrence) and revealed a reduction in biomass up to 31.8 t ha^{-1} for the area inside the national park due to elephant grazing. Fires inside the park leveraged elephant's effect by killing young sapling and debarked susceptible trees. [32] and [46] analised the combined effect of fires and elephants in NNR, northern Mozambique, revealing denser woodlands and higher wood biomass in places with low fire frequency and low animal densities. Recently, [48] studied the dynamics of the biomass in the Miombo woodlands in NNR and observed that woody biomass had a net increase of 3 Mg ha^{-1} in a 5-year period of study. However, when looking at the species level, *Diplorhynchus condylocarpon* presented the highest growth (a net increase of 0.54 Mg ha^{-1}). This species has been reported elsewhere in the region has fire indicator due to its capacity to thrive in high fire frequency environments and to the fact that it is less preferred by elephants. *Julbernardia globiflora* (Benth.), on the other hand, experienced a net decrease in biomass of 0.09 Mg ha^{-1}. The reason might be associated with fire susceptibility as well as high preference by local population and elephants and. As referred above, not many studies have addressed the specific responses to disturbances, though it should be considered fundamental

to understand the ecosystem trends. In fact, species dynamics may disclose particular behaviors that are not seen at the ecosystem level, but are important in defining conservation and management strategies, which are not just ecosystem but also species oriented.

Charcoal production is one of the main drivers of Miombo degradation but has been poorly accounted for in biomass and carbon studies. Only one study [57] was found in the literature. This study was conducted in Zambia, by comparing a protected area with a highly disturbed site. The results revealed considerably reduced biomass after logging for charcoal production -150 t ha^{-1} within *versus* 24 t ha^{-1} outside the protected area. The authors discuss that better inventory data is urgently required to improve knowledge about the current state of the woodland usage and recovery after logging. They further argue that net greenhouse gas emissions could be reduced substantially by improving the post-harvest management, charcoal production technology and/or providing alternative energy supply.

Although soil is one of the main carbon pools in Miombo, studies that deal with this component are limited [28,48,58-59]. [28] observed that woodland soils were capable of storing >100 t C ha^{-1}, whereas in re-growing areas soil carbon stocks did not exceed 74 t C ha^{-1}. The study concluded that there was a potential for C sequestration in soils on abandoned farmlands. However, there was no discernible increase in soil C stocks within the period of re-growth, suggesting that the rate of accumulation of organic matter in these soils was very slow. On the other hand, [58] observed that agricultural soils in Malawi had 40% less carbon than mature Miombo Woodlands. The authors stated that as the area of land converted to agriculture increases in the region, land in this re-growth state will most likely become the dominant form of Miombo. Therefore studies of the nutrient dynamics in this type of land cover will be essential.

Understanding biomass and carbon recovery (along with biodiversity) rates is essential to predict future scenarios of ecosystem stock densities and thus, its capacity to provide goods and services. Short to medium term (16-50 years) studies in the region reveal a capacity for stock regeneration between 1.0 and 1.8 M g ha^{-1} yr^{-1} [1,28,43,60]. In Zambia, [31] reported net changes in aboveground biomass over a 22-year period of -113.4 Mg (-5.16 Mg ha^{-1} year^{-1}) and 25.7 Mg (1.17 Mg ha^{-1} year^{-1}) associated with old-growth and re-growth sites, respectively. Biomass loss in old-growth sites was driven by agriculture and fire. The conclusion drawn from these studies indicated that Miombo has capacity to recover after disturbances but at slow rates. The latter can be exacerbated or reverted by recurrent disturbances, compromising ecosystem resiliency. However, given the limited number of studies and the associated short to medium time spans, there are still knowledge gaps such as: i) which species recover and at which rate; ii) what are the thresholds of changes relation to disturbances; iii) what are the rates of soil carbon recovery. Improving the knowledge on recovery rates and patterns is important given the complexity of the ecosystem associated with the varied environmental gradients across the region.

3. Research gaps and management needs

It is evident that there have been a considerable amount of studies undertaken in the Miombo Woodlands. In July 2013 the Miombo Network of Southern Africa met in Maputo, Mozambique to discuss the existing knowledge and gaps. In general, there is a consensus that much is still to be investigated.

Miombo displays complex vegetation patterns in which dense vegetation alternates with sparsely populated or bare soil in response to environmental and disturbance (deforestation/degradation, fires and herbivory) factors. Low vegetation cover, in some places, and small-scale variations in others, can produce unpredictable errors in the quantification of ecosystem dynamics. Ignoring this spatial variation can produce inaccurate results, even in fairly homogeneous environments [61-62].

Miombo complexity has introduced limitations in the past in terms of accurate estimations/mapping of Land Cover and Land Cover Change (LCLCC), biomass/carbon and biodiversity. In fact, there have been several attempts to estimate LCLCC and biomass at the local and national scale, but at the regional level there is still a need to improve and update the existing products. Land cover mapping is important to delineate LC types associated with degradation levels and the role of the associated drivers. The latter is highly relevant in determining the role of ecosystem in the carbon cycle as well as in defining appropriate rehabilitation and conservation strategies. These are particularly important in the context of REDD+ as it would be important to demarcate areas of interest to develop REDD+ projects.

Ecosystem rehabilitation requires a good understanding of its past and present status including the specific and interactive role of the drivers (fire, herbivory, slash and burn agriculture and climate change) as well as of its recovery patterns across environmental gradients. It also requires a better understating of its biodiversity beyond floristic surveys. In this context, the following questions need to be answered:

- What are the impacts of the different ecosystem drivers on biodiversity?

- What is the capacity of biodiversity to supply and underpin goods and services (current and future)?

- What are the patterns of genetic diversity of important species across environmental gradients?

- How different land cover types affect the existing patterns of biodiversity?

- How these changes in biodiversity affect the availability and accessibility of resources to rural and urban dwellers?

It is important to recognize that biomass and carbon estimations are very scattered in terms of methods and sampling efforts recalling a need to perform harmonized estimations to better position the region in the international context. Hence, finding benchmark sites is vital as it allows determination of deviations under different land uses. This is particularly important

given the fact that the diversity of soils, climate, hydrology and disturbances return highly variable biomass and carbon densities making a comparison among sites not always possible [28,49]. Biomass estimations are also relevant to understand the contribution of different pools (soils, grasses, litter, etc) as well as the role of drivers in the ecosystem biomass/carbon sequestration. Particularly in the case of soil carbon, efforts should focus on identifying and protecting C-rich soils. It is also important to investigate whether fire control on recovering woodlands can stimulate the accumulation of soil C and tree biomass, and hence restore defining Miombo species.

Finally, the use of modern (*e.g.* remote sensing and molecular markers) and harmonized sampling data collection and analysis techniques across the region would contribute to the robustness of data and support improved ecosystem management and conservation strategies.

4. The role of the Miombo Network in promoting the Miombo Woodlands sustainability

Founded in 1995 by a group of regional and international scientists, the Miombo Network is under the auspices of the IGBP/IHDP Land Use and Cover Change (LUCC) Project and the IHDP/IGBP/WCRP Global Changes System for Analysis, Research and Training (START). The Network's goal was to support the development of sustainable Miombo Woodlands management policies and practices through the collaborative data acquisition, from land-based research, monitoring, remote sensing and other geospatial information technologies. The membership of the network is drawn from government, university and research institutions of the Miombo Ecoregion countries namely: Malawi, Mozambique, Tanzania, Zambia and Zimbabwe. However, there are also member institutions outside Africa due to their passion for Miombo management.

Being a collaborative alliance, the Miombo Network aspires to conduct joint research that contributes to forest policy definition and decision-making. The entry point for this is a strong link with the SADC forestry program, which intends to develop harmonized policies for the region. The Miombo Network has also potential to contribute for the establishment of the REDD+ programme - a programme that has great potential to turn around the economic and environmental value of the ecosystem across the region.

5. Final considerations

Despite being considered the most important ecosystem of southern Africa, the Miombo Woodlands face some risks. Although policies may be supportive as far as Miombo management is concerned, the woodlands continue to be degraded and deforested. Partly, this is due to the fact that institutions that are responsible for managing the forests have limited human and financial capacity. Additionally, Community-Government partnerships for woodland

management need to be enhanced in the region. It would therefore be important that national, regional and international institutions put more effort to establish effective collaborations in order to understand the interplay of issues that affect the management of Miombo Woodlands.

Acknowledgements

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