# A contribution to Mozambique's biodiversity offsetting system: framework to assess the ecological condition of Miombo Woodlands

**Final Report**

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## ACRONYMS

| Acronym | Description |
|---|---|
| BOE | Metric for Biodiversity Offsetting Pilots in England |
| BV | Germany's Biotope Valuation |
| DRC | Democratic Republic of Congo |
| EIA | Environmental Impact Assessment |
| FIAT | Forest Integrity Assessment Toll |
| IFC | International Finance Cooperation |
| IVI | Importance Value Index |
| MITADER | Ministry of Land, Environment and Rural Development |
| MIREME | Ministry of Mineral Resources and Energy |
| NNL | No Net Loss |
| NG | Net Gain |

## DEFINITIONS

**BIODIVERSITY METRIC: a framework designed to quantitatively assess the ecological condition of an ecosystem.**

**CLUSTER**: sampling unit of 1ha (100 x 100 m), which is a conglomerate of four plots (20 x 50 m) located in the four corners of the square cluster.

**DENSE MIOMBO:** part of the Mozambican forest category of Semi-deciduous Forests with a canopy cover above 50%. Usually correspond to an undisturbed state of Miombo.

**DEGRADED MIOMBO:** forest area that has been converted to a different land use (canopy cover less than 30%) or one or more of its ecosystem services is compromised.

**ECOLOGICAL CONDITION:** state of ecological systems, which include their physical, chemical, and biological characteristics and the processes and interactions that connect them. In this study ecological condition is measured as the state of the biological characteristics as an expression of other characteristics in the system relative to the benchmark.

**FOREST:** A piece of land with trees with the potential to reach a height of 3m at maturity, a canopy cover equal or greater than 30%, and that occupy at least 1 ha.

**OPEN MIOMBO:** part of the Mozambican forest category of semi-deciduous forests (DINAF, 2018) with a canopy cover between 30-50%. Open Miombo can be an ecological mature state in dry and coastal areas or a transition state between degraded and intact Miombo.

**UNDISTURBED MIOMBO:** a closed deciduous non-spinescent woodland dominated by three tree genera: *Brachysregia, Julbernardia* and *Isoberlinia*, occurring in geologically old, nutrient-poor soils in the uni-modal rainfall zone (600-1400 mm in one season). The shrub layer is variable in density and composition. The ground cover varies from a dense coarse grass growth to a sparse cover of herbs and small grasses. Anthropogenic fires and herbivory are key ecological features of Miombo woodlands

# 1. Introduction

Over the last decade there has been a significant increase in the exploitation of natural resources in Mozambique as well as the development of infrastructure, which have resulted in a number of negative environmental and social impacts. Consequently, there is an urgent need to find ways to reconcile the economic development of Mozambique with the conservation of biodiversity and ecosystem services, upon which over 80% of the population directly depends.

A promising approach that has been used internationally to attempt to reconcile economic development and biodiversity conservation is the implementation by project developers of the *mitigation hierarchy*[1] which requires them to avoid and minimize impacts, restore biodiversity and ecosystem services in impacted areas, where possible, and if significant but acceptable residual impacts persist, design and implement biodiversity offsets, according to an appropriate management plan, in order to achieve No Net Loss (NNL) or a Net Gain (NG) of biodiversity. A key driver for the adoption of the mitigation hierarchy was and remains compliance with environmental standards and guidelines established by financial institutions (e.g. IFC, World Bank, bilateral donors, etc.) and some sectorial associations (e.g. Equator Banks[2]).

There is a growing consensus around the NNL/NG goal in Mozambique, in the business sector as well as within key ministries such as the Ministry of Land, Environment and Rural Development (MITADER) and the Ministry of Mineral Resources and Energy (MIREME). Biodiversity offsetting is seen as a valuable tool to mitigate negative impacts from large-scale and/or high-risk development projects and to attract investors committed to international best practices for biodiversity and ecosystem services management. Various private sector companies, particularly multinationals operating in the country, have expressed a clear commitment to such international best practice standards. A national compliance framework would assist investors in fulfilling their obligations to comply with the performance standards of financial institutions, while requiring the same level of environmental performance from all project developers. In 2016, the World Bank funded the development of a *RoadMap for a No Net Loss Aggregated System including Biodiversity Offsets for Mozambique* (Biofund 2016). This roadmap continues to guide the development of policy and implementation options in the country.

[1] Mitigation hierarchy, commonly applied tool in Environmental Impact Assessments (EIAs) that includes a hierarchy of steps to limit impacts on biodiversity: Prevention (or avoidance), Minimization, Rehabilitation/ Restoration and Biodiversity Offsets. Adapted from BBOP 2012.

[2] 94 financial institutions in 37 countries have adopted the Equator Principles, including banks operating in Mozambique such as Standard Bank, Societé General, Barclays and Nedbank.

Offsets aim to achieve NNL/NG of biodiversity by explicitly addressing residual impacts from a project, and this goal should apply to all components of biodiversity that are significantly impacted: species, habitats or ecosystems. In many cases, the focus should be essentially on habitats and the ability to discern their ecological condition. To ensure this objective is achieved it is necessary to measure biodiversity losses from impacts and the gains required and achieved from offsets in a practical and transparent way so that their equivalence can be compared and adequacy of an offset established.

However, measuring losses and gains in biodiversity is not straight forward due to its complexity and context-related variability (Zambello et al. 2019). To enable measurement, proxies are often used (e.g. ecosystems or habitats that represent biodiversity more generally) and metrics are then defined for these biodiversity features so that the amount of biodiversity loss from impacts and the amount gained from offsets can be quantified and compared to establish if NNL or NG are achievable and achieved (Marshall et al., in press). High levels of uncertainty inherent in quantifying biodiversity features, and changes over time in response to frequently complex sets of interacting drivers must be considered in constructing appropriate metrics (e.g. to build in defensible margins of error). At the same time, metrics have to be practical to enable measurement within reasonable timeframes and resources.

In this context, there is a need to determine how to measure the condition of ecosystems for Mozambique in a pragmatic way. For the Miombo woodlands in particular, a framework of ecological assessment is justified by the fact that it is the most extensive forest ecosystem in the country thus representing a significant portion of national biodiversity (DINAF, 2018). On the other hand, this is a quite well studied ecosystem in the country and there exist national experts in Miombo. This set of conditions will facilitate the definition of a solid framework for the country, which will contribute to the establishment of appropriate metrics for the offsetting system in Mozambique. Given the country's limitations and specially the Miombo ecological variability it is important that this initial exercise focus on ecosystem condition, which is a challenging part of any robust metric and important for understanding / quantifying losses and gains.

This assignment aims to propose a framework to assess Miombo ecosystem condition in Mozambique. To achieve the main objective we followed the systematic procedure that included: analysis of international best practices, selection of a few metrics that can be adapted to the Mozambican condition, testing the selected methodologies using existing data for Miombo, sensitivity analysis and decision about the appropriate metric. The steps used in this study were widely discussed with national and international experts through email exchanges, skype call, and meetings, among others. This report is organized in the 6 sections:

1. **Introduction**: refers to context and importance of this assignment

2. **Brief description of Miombo woodlands**: provides a summary of the ecological condition of Miombo.
3. **Methodological process**: describes in details the steps conducted towards selecting the metric.
4. **Results and Discussion**: compiles the information in terms of the ecological condition of Miombo and the metrics tested.
5. **Final consideration**: summarizes the work and provides indication of the needed improvements in the future
6. **References**: provides a list of references used in this assignment.

# 2. Brief Description of the Miombo Woodlands

## 2.1. Miombo woodlands ecology

The Miombo woodlands form a transitional system between the closed rainforests in central Africa and open semi-arid savannas of southern Africa (Vinya 2010), holding the bulk of the Earth's tropical dry forest biomass (about 43 % of the world's tropical dry forests) and one of the last remnants of megafauna (Mittermeier 2003). Miombo covers ca. of 2.7 million $km^2$ across 7 countries (Mozambique, Malawi, Zimbabwe, Tanzania, Zambia, Angola and south of DRC) (Figure 1; Frost 1996). Ecosystem services derived from the woodlands are key in determining socio-economic development and sustain over 100 million people in rural areas and over 50 million urban dwellers in the region (Ryan et al. 2016). From the environmental point of view, the woodlands are key to regulate the local and regional climate by sequestering 18-24 PgC (Ryan et al. 2016), water and soil cycles, amongst many other things.

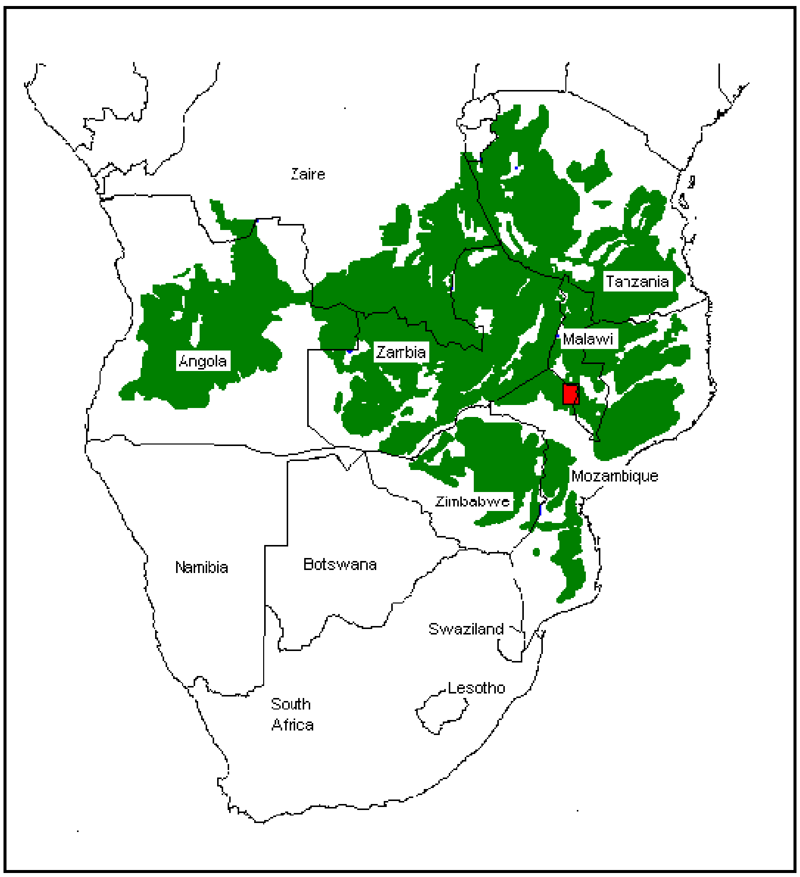



**Figure 1: Regional distribution of Miombo woodlands in Southern Africa (Source:** Voortman and Bindraban 2017).

Miombo woodlands occur in relatively nutrient-poor soils and in regions with more than 700 mm of annual precipitation. Miombo is characterized by the overwhelming dominance of three tree genera: *Julbernardia, Brachystegia and Isoberlinia*, which encompass a uniform umbrella-like canopy cover that varies between <20% to over 80% (Ribeiro et al. 2015). The diversity of tree species is relatively low compared with tropical forests, but the overall plant diversity is considerably high with an estimated 8,500 plant species, half of which are endemic to Miombo woodlands (Frost 1996).

Miombo distribution in southern Africa crosses a precipitation gradient from dry (less than 800 mm mean annual precipitation, MAP) in Zimbabwe and eastern and central Mozambique (with influence of coastal elements in some places) to wet (more than 1000 mm MAP) in north-eastern Zambia and southern DRC (Frost 1996). Accordingly, the ecosystem is usefully divided into at least two types – wet Miombo and dry Miombo – each with intrinsic ecological dynamics, different species assemblages and conservation attributes (White 1983, Timberlake & Chidumayo 2011, Frost et al. 2002).

Miombo ecology is determined by its woody component, which in turn is influenced by climate, soils and disturbances such as: fires, herbivory and several human activities (agriculture, charcoal production, honey gathering, etc.; Frost 1996). Structurally, Miombo is composed of 2-3 strata: upper (canopy trees), medium (shrubs and natural regeneration of canopy species) and lower (grass and herbaceous species). The woody component comprises 95% of the biomass, while the remaining 5% are split between the grass, herbaceous and shrubby components (Frost 1996). Immersed in the Miombo landscapes are the hydromorphological formation called *dambos*, which are grass formations in seasonally flooded depression composing up to 40% of the landscape (Timberlake and Chidumayo, 2011). These are key to maintaining key herbivore populations and thus the ecosystem's stability and vice-versa.

White (1983) defined two categories of Miombo, Wet and Dry, according to the precipitation zone in which they occur. Wet Miombo woodland occurs over much of eastern Angola, northern Zambia, southwestern Tanzania and central Malawi in areas receiving more than 1000 mm rainfall per year. Canopy height is usually greater than 15 m, reflecting the generally deeper and moister soils. The vegetation is floristically rich and includes nearly all of the characteristic miombo species: *Brachystegia floribunda*, *B. glaberrima*, *B. longifolia*, *B. wangermeeana*, *Julbernardia paniculata*, *Isoberlinia angolensis* and *Marquesia macroura* are widely distributed. The understorey comprises a mixture of grasses, bracken (*Pteridium aquilinum*) and shrubs, including the monocot *Aframomum biauriculatum*. Despite the density of the overstorey, the dominant grasses are: *Hyparrhenia, Andropogon* and *Loudetia* (White 1983). The Dry Miombo woodland occurs in southern Malawi, Mozambique and Zimbabwe, in areas receiving less than 1000 mm rainfall annually. Canopy height is less than 15 m and the vegetation is floristically impoverished. The dominant Brachystegia species of the wet miombo woodland are either absent or local in occurrence. *Brachystegia spiciformis, B. boehmii* and *Julbernardia globiflora* are the dominant deciduous species. The herbaceous layer varies greatly in composition and biomass and includes grasses (mainly of the genera *Hyparrhenia, Andropogon, Loudetia, Digitaria* and *Eragrostis*), sedges, shrubs (e.g. *Eriosema, Sphenostylis, Kotschya, Dolichos* and *Indigofera*), and sup- pressed saplings of canopy trees.

According to Frost (1996) over most of its range, mature undisturbed Miombo is physiognomically closed deciduous woodland within the spectrum of savanna ecosystems (Walker 1981, Huntley 1982), grading into seasonal dry forest at above 1200 mm mean annual precipitation. Nevertheless, at any point there can be considerable heterogeneity in tree height, canopy cover and herbaceous structure, reflecting the variation in soils and the impacts of fire, land use, herbivory and other disturbances. The overriding feature that gives coherence to this diversity is the floristic uniformity of the vegetation, namely the dominance of genera in the family Fabaceae, subfamily Caesalpinioideae, particularly *Brachystegia, Julbernardia* and *Isoberlinia*.

Anthropogenic historic fires represent 95% of Miombo fires, which is not surprising as fire is widely considered an accessible management tool (Frost 1996). Several studies in the region indicate that fires every 3-4 years are important in maintaining structural and compositional elements in this ecosystem. However, modifications in fire frequency and intensity, e.g. due to climate change or human population growth, may impact the relationship between the ecosystem and fires and thus cause further changes in the ecosystem. These in turn, may contribute to modifying ecosystem services, with a cascade of consequences at different levels. These modifications may also be introduced by direct interference of growing human populations on the ecosystem through conversion to agriculture, charcoal production, logging, hunting/poaching, infrastructure development to mention a few. Thus, it is important to address the condition of the ecosystem in order to avoid further losses and/or degradation of Miombo and its biodiversity. This complexity of factors (fires, people and climate change) makes it exceptionally complex to define condition reliably for the woodlands. Fire is a very complex phenomena to address in Miombo and its management is likely to be an important feature of Miombo management on set-asides (avoidance) and in protected areas (offsets).

In order to deal with the complexity associated with Miombo, this assignment considers the definition of **mature undisturbed Miombo (reference ecosystem)** given by Campbell et al. (1996): a closed deciduous non-spinescent woodland occurring in geologically old, nutrient-poor soils in the uni-modal rainfall zone (600-1400 mm in one season). The shrub layer is variable in density and composition. The ground cover varies from a dense coarse grass growth to a sparse cover of herbs and small grasses. Anthropogenic fires and herbivory are key ecological features of Miombo woodlands.

## 2.2. Brief characterization of Miombo woodlands in Mozambique

According to White (1983) the Mozambique falls within two main regions, the Inhambane-Zamzibar Coastal Mosaic and the Zambezian Regional Center of Endemism (ZRCE). The former covers most of the coastal belt from Maputo to Cabo-Delgado Provinces and it is 50-200 km wide except when it penetrates inland along river valleys (Figure 2). The vegetation types in this mosaic are diverse but dominated by scrub woodland and edaphic grasslands, which have been largely modified by human activities (White, 1983). Southwards, a floristically impoverished type of Miombo woodland becomes increasingly important, this is where our study area (the Pomene National Reserve-PNR) falls in. The ZRCE covers large inland areas in Mozambique and is composed of many different vegetation types including the dry and wet Miombo woodlands (Figure 2).

In Mozambique, Miombo woodlands occur north of the Save river (north of Inhambane to Niassa and Cabo-Delgado Provinces) with a small fringe extending to the south of the Save river and cover over 65% of the land in the country (Marzoli 2007). The last national forest inventory indicates that forests cover 40% of the land in the country and 33.7% of this correspond to semi-deciduous forests, of which Miombo is the majority, but there is no exact figure of Miombo distribution in the country (DINAF 2018).

Wetter and Drier Miombo have been broadly described by Ribeiro et al. (2002):

**Wet Miombo:** occurs above 800 m above sea level (asl) in areas with MAP above 800 mm, in undulated topography. The areas of occurrence include: Chimoio plateau in Manica Province, parts of Sofala Province (e.g Inhaminga and Marromeu), highlands of Zambezia Province such as: Ile, Namarrói and plateaus adjacent to Gúruè, Náuèla, Alto Molocué, Tacuane and Milange. It is dominated by *Brachystegia spiciformis*, associated with *Pteleopsis, Erythrophleum* and *Newtonia*. Trees are of 15 to 22 m high, with closed canopy and low grass and herbaceous components.

**Dry Miombo:** occurs in areas of low altitude between 50-800m asl, with MAP of 600 to 800 (1,000) mm. It is the most widespread type of Miombo in Mozambique and is found across the lowlands of Manica, Sofala, Tete, Zambezia and Niassa, and north of Inhambane and Gaza (with precipitation of 400-800 mm). The dominant tree species are: *Brachystegia boehmii, Julbernardia globiflora, Burkea africana, Pseudolachnostylis maprouneifolia, Crossopterix febrifuga, Diplorhynchus condylocarpon*, etc. Variations of these species composition occur towards the coast and the highlands where other tree species may occur associated to Miombo indicator species. Species belonging to the Combretacea family may occur and dominate in sandy soils and where disturbances such as fires are intense (Chidumayo 1997). Trees are 8 to 10 m high sparsely distributed in a canopy cover of not less than 20% of the ground and a very abundant grass/herbaceous component.

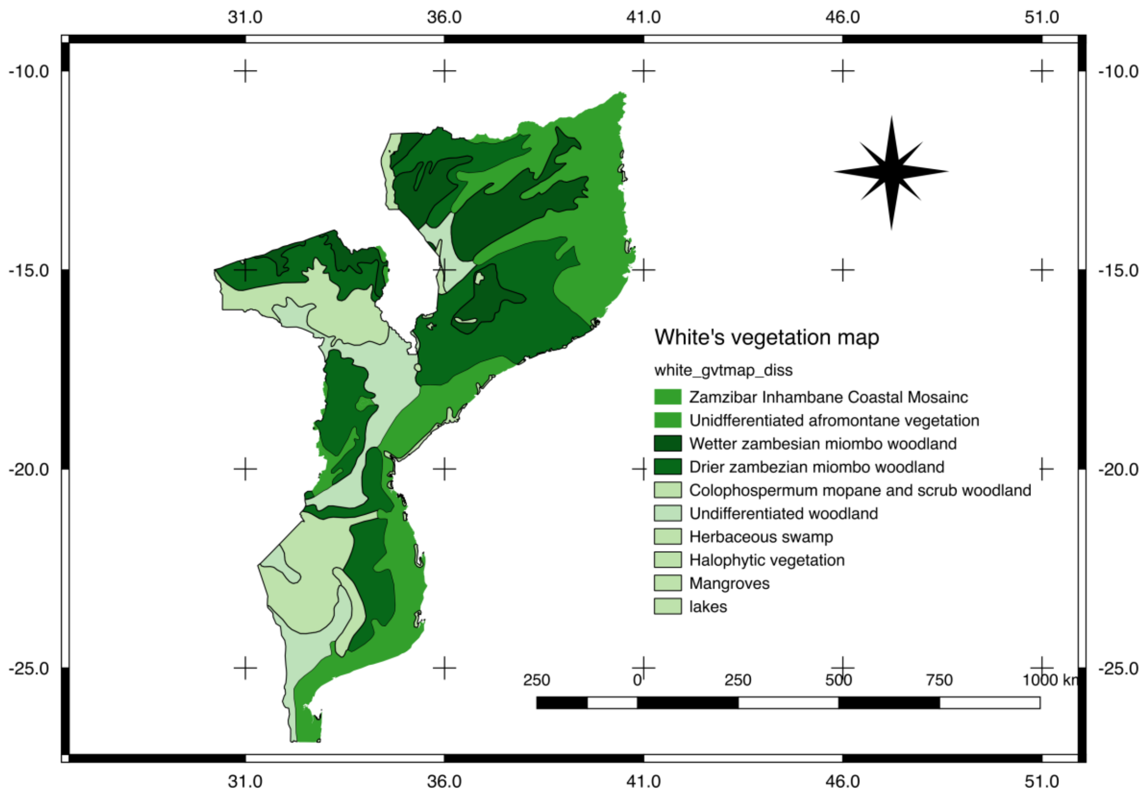



**Figure 2: Vegetation types of Mozambique (Source: White, 1983).**

According to Burrows et al. (2018) the main Miombo woodland types namely: Coastal Miombo, the Rovuma coastal, Deciduous Miombo savannah, Submontane Miombo, Semi-decidous northern plateau Miombo, Escarpment Miombo, Niassa lake Miombo, Decidous mixed coastal. This classification is based on Wild and Barbosa's (1967) classification and the range of habitats and vegetation types that are found in Mozambique. Our study area likely falls within the coastal Miombo (open Miombo) and the Inhambane-Zambezi sand forest (dense Miombo), which presents elements of Miombo.

Given the fast land use and land cover changes in the last 10-20 years in Mozambique, Miombo has been substantially intervened by human activities especially agriculture, charcoal production, mining and infrastructure development among others. The direct implication is that in some areas the woodlands might be a state of transition that do not exactly correspond to Campbell's definition of undisturbed Miombo used in this study. But, it is important to consider that Miombo is a resilient ecosystem and thus can return to its original state in 15-20 years after disturbances are removed. Under this context, defining an ecological condition (including benchmarks) for Miombo is very challenging and any methodological pragmatic approach should consider those local variations associated to the history of land use in the area.

# 3. Methodological process

In order to design a metric of Miombo's ecological condition adapted to the national context our approach comprised of the following steps:

- Compilation of indicators and benchmarks of Miombo ecological condition;
- Analysis of international best practices;
- Adjustment and test of metrics for the Miombo conditions;
- Technical meeting with key stakeholders;
- Consultation with international experts;
- Field data collection and analysis;
- Sensitivity analysis;
- Selection of the metric for Miombo woodlands in Mozambique; and
- Validation at a national workshop with key stakeholders.

## 3.1. Compilation of indicators and benchmarks of Miombo ecological condition

In this first phase the team analyzed Miombo woodlands related literature and based on the team's expertise produced a long-list of indicators (Annex 1). This long list was analysed and discussed with national and international experts aiming to define robust and pragmatic indicators for the Mozambican context. The following criteria for selection of the final list of indicators were used in this process:

(i) **Existence of information on benchmarks**: these are important references to indicate intact/untouched Miombo condition. Benchmarks were defined based on existing studies (e.g. Ribeiro et al. 2013; FAEF 2017; DINAF 2018, among others). As referred by Yen et al. (2019) identifying long- undisturbed reference states is complicated by, among other things, the fact that undisturbed states may be unattainable in contemporary and future systems due to ongoing changes in species composition, climate, and landscape configuration. This is particularly relevant in the Mozambican context as referred in section 2.2. Thus, the reference levels used in this study should be revised periodically as more data is collected across the country. In places where undisturbed Miombo still exist locally, the benchmarks should be defined according to the local ecological condition.

(ii) **Practicality of data collection and analysis**: given the national context of limited expertise and resources it is key that the indicator is easily assessed in the field and the methods for data analysis are not complicated, i.e. they are straightforward in terms of the formulas they use.

(iii) **Reduced redundancy of information**: indicators providing the same information about the ecosystem do not bring added value to the framework and otherwise may turn it into an expensive and complex process. Thus, for redundant indicators we selected the one that is more robust and easy to measure in the field; E.g. soils condition *vs* basal area, select basal area which is an expression of the soil condition and faster to assess.

(iv) **Complexity of Miombo landscapes**: given the historical presence of fires and herbivory these landscapes are very complex and some indicators can be very volatile (e.g. presence of grass may vary according to fires/herbivory/landscape and season) and thus bring a wrong perception of Miombo condition.

Based on the criteria above and on discussions with experts we produced a short-list of indicators and respective benchmarks (Table 1).These indicators have also been considered important in defining Miombo ecological condition at the site and landscape levels in several studies (Frost 1996; Chidumayo 1989; Ribeiro et al. 2008; Ryan et al. 2010; Gonçalves et al. 2017; among many others). Here we considered that most Miombo woodlands in Mozambique belong to the dry to sub-humid categories and the existing data (to test the metrics) and benchmarks belong to those classes and thus we focus on these two types of Miombo. However, we acknowledge that the humid Miombo exists in Mozambique and a definition of benchmarks and respective metric definition shall be considered in the near future.

**Table 1: Selected Miombo indicators and benchmarks for Miombo condition assessment.**

| **Component of Site Condition** | **Benchmark for Miombo in Mozambique** | **References** |
|---|---|---|
| Tree canopy cover (%) | 30-59 (open)<br>>60 (dense) | Frost (1996)<br>Ribeiro et al. (2008)<br>Marzoli et al. (2008).<br>DINAF (2018) |
| Canopy height (m) | 8-12 | Frost (1996)<br>Ribeiro et al. (2008)<br>DINAF (2018) |
| Basal area ($m^2$/ha) | 8-10 | Frost (1996)<br>Ribeiro et al. (2008)<br>DINAF (2018) |
| Tree density (dbh≥5 cm; N/ha) | 400-500 | Frost (1996) |

| | | |
|---|---|---|
| | | Ribeiro et al. (2008)<br>DINAF (2018) |
| Recruitment (Saplings with 5≤DBH<10) (N/ha) | 150 | Ribeiro et al. (2008) |
| Miombo indicator species (*Brachystegia boehmii, B.spiciformis, Julbernardia globiflora)* | 22% of total species | Ribeiro et al. (2013)<br>DINAF (2018) |

Initially, woody biomass was also considered in this table however given the lack of specific allometric equations for each species found, the actual calculation was only done on the basis of dbh, which meant in practice that it was measuring the same information as basal area. It was therefore removed from the list.

Recruitment was also not analysed as a separate indicator, following consultation it was decided that it was adequately incorporated into the overall density calculation and did not need to be separated out.

## 3.2. Analysis of international best practices in determining habitat condition in offsetting systems

Offsets are emerging as an appealing solution for managing development impacts on biodiversity, with the stated aim of achieving no net loss (NNL) or net gain (NG) of biodiversity. Their growing use, in a range of countries worldwide, has generated an abundant literature on how best to compare biodiversity losses and gains in the context of the mitigation hierarchy.

The literature review revealed that there is an emerging consensus on basic principles for assessing condition in the context of the mitigation hierarchy, but detailed guidance often remains elusive (McKenney & Kiesecker 2010). In the early offset projects, area alone was the currency used: the area impacted was offset by at least an equal area elsewhere (King and Price 2004). However, as the importance of considering ecosystem function grew, area alone was no longer considered adequate (Parkes and Newall 2003; Quetier and Lavorel 2011). Several methods have been developed to supplement area measurements in order to account for multiple biodiversity dimensions such as the condition, quality, ecological function and integrity of ecosystems (Gonçalves et al. 2015). Much recent scientific literature attempts to deal with the multiple theoretical challenges of determining quality, often recommending ever more complex measurements and aspects for consideration (Bezombes et al. 2018 for example recommend the use of 107 distinct indicators). It is clear that there is a substantial divergence in biodiversity outcomes when using different metrics for calculating the gains required to offset the same development (Strange et al. 2002; Bull et al. 2014), and that no assessment method combines all the various challenges perfectly (Bezombes et al. 2017; Zambello et al. 2019). In practice however, excessively complex methodologies will be too difficult or costly to implement and monitor, and is likely to lead to low levels of implementation in spite of ambitious policy goals (Gonçalves et al. 2015). Technical issues such as metrics and exchange rules for offsets are only one of the challenges to be addressed in order to achieve NNL/NG in practice (Bull et al. 2013) and it is important to provide methods for designing and sizing appropriate offsets that are both pragmatic and defensible enough that they can actually be implemented under the national available capacity and EIA timelines.

Different methods focus on different target components of biodiversity and ecosystems depending on the specific target of the applicable NNL/NG policy (Quetier and Lavorel 2011). The international systems, which were reviewed in the present study with respect to the metrics they apply are presented in Table 2.

**Table 2: List of international best practices analysed in the study.**

| Number | Metric System | Acronym | Reference |
|---|---|---|---|
| 1 | Wetland banking in the United States | | FWS, 2003 |
| 2 | Habitat and Resource Equivalency Analysis in the United States | HEA and REA | Strange et al. 2002; Dunford et al., 2004 |
| 3 | Habitat Hectare approach used in Victoria, Australia (Vegetation quality Assessment Manual) | VQAM-HH | Parkes et al., 2003 |
| 4 | Brazilian Native Forest Protection System | | Sparovek et a;l., 2012; Soares-Filho et al., 2014 |
| 5 | Natura 2000 network of protected areas under the European Habitats directive | | |
| 6 | Metric for Biodiversity Offsetting Pilots in England | BOE | DEFRA, 2012 |
| 7 | Canadian fish habitat | | Minns et al., 2001; DFO, 2002 |
| 8 | South Africa’s Western Cape offset guidelines | | DEADP, 2007 |
| 9 | Conservation Significance Index | CSI | Sawmy et al., 2014 |

| | | | |
|---|---|---|---|
| 10 | Germany’s Biotope Valuation | BV | German Impact Mitigation Regulation- *Eingriffsregelung* |
| 11 | South Australia’s Significant Environmental Benefit | SEB | Department of Water, Land and Biodiversity Conservation, State of South Australia, Australia |
| 12 | Switzerland’s Module Assessment Method | MAM | Federal Office for the Environment – FOEN; Switzerland |
| 13 | Biodiversity Offsets Accounting Model for New Zealand: User Manual | | Maseyk et al.(2015) |
| 14 | Forest Integrity Assessment Tool | FIAT | Proforest, HCV Resource Network and WWF |
| 15 | Madagascar Ambatovy mine metric (a redacted version of the Victoria habitat hectare approach) | Ambatovy | BBOP Ambatovy case studies: Berner et al. 2009 and von Hase et al. 2014 |

Overall our analysis of the above mentioned methodologies revealed that not all of them can be applied or adjusted to our context as some of them do not apply strictly to measure ecosystem condition but to the overarching methodology for determining NNL/NG.

Ultimately all methodologies must calculate the total area to be included in the offset location. This must always be based on the area affected by the economic development in question. The metrics reviewed here can be grouped into three main approaches to reach this end goal.

The first group are metrics that use indicators to calculate an overall multiplication factor, which is then applied to the impacted area to determine the area of the offset. Since habitat condition is usually only one of these factors, the quality index is usually only a three to six point scale. These include the BOE, BV, SEB or South African models, amongst others.

The second group are those methodologies that try to quantify habitat condition, often referred to as habitat hectares, such as the VQAM, MAM or the Ambatovy mine metric. These methodologies usually then multiply area by the quality assessment in both the impact and offset sites to determine equivalence. Since habitat quality is the principle aspect measured in these systems, it is generally a much more detailed process, leading to a much more precise quality score, often expressed in percentages.

A third group of methodologies focuses on specific species, and tend to calculate the offset area based on the size needed to sustain a given population of that (those) species. Examples of this are the CSI, Canadian Fish habitat method or the European Habitat Directive. Here, habitat quality is principally focused on the services it provides (e.g. food, shelter, breeding requirements) to these key species, and so it is these specific aspects that are quantified.

Given the fact that the overall system for determining offset size has not yet been finalized, it is difficult to know which kind of habitat condition metrics to produce. Even with this limitation, we selected the methods deemed to be more oriented to our objective of measuring Miombo ecological condition. The selected metrics were adapted and tested for the Mozambican conditions (Table 3), by using a combination of literature review, expert consultation and statistical analysis of field data, which are described below.

**Table 3: Selected international metric systems for Miombo ecological condition: applicability, adaptation made for Miombo woodlands and limitations in the Mozambican context.**

| Metric name | General description | Indicators | Applicability of indicators to Miombo in Mozambique | Adaptation to Miombo woodlands in Mozambique | Limitation for application in Mozambique |
|---|---|---|---|---|---|
| Habitat Hectare approach (VQAM-HH) | Uses a set of indicators that describe vegetation condition and its landscape context (nature of landscape surrounding the site) aggregated in a weighted score. | •**Site Condition indicators:** number of large trees present, tree cover, understory components, lack of weeds, recruitment, organic litter, logs.<br><br>•**Landscape Condition indicators**: patch size, neighborhood, and distance to core area. | Most site condition indicators are applicable, but had to be adjusted to include some specific Miombo condition.<br><br>Landscape indicators are applicable but not pragmatic in the Mozambican context, given limited resources and EIA timelines. | 13 indicators of site condition: % canopy cover, Canopy height, % grass cover, % large dead trees, % of invasive/domestic species, % of Miombo indicator species, % of fauna indicators, % of saplings, % of regrowing stumps, % of organic matter, % of woody biomass, % of human activity (agriculture, charcoal, timber), % of fire resistant species. Note: all % are relatively to the benchmarks defined in section 3.1. (Annex II). | • Too many indicators;<br>• Some complex to measure in the field<br>• Lack of benchmarks for some indicators.<br>• Limited number of skilled field operators<br>• Not all indicators are meaningful to measure site condition in Miombo systems. |
| Metric for Biodiversity Offsetting Pilots in | Variation of the HH approach, in which the value of habitats is determined on the basis of 3 criteria: | • **Distinctiveness**: rarity of<br><br>habitat, species composition. | Not immediately applicable due to the fact that it is based on a very fine typology of habitat types, many of | • BOE1:<br>Miombo indicators species (*Brachystegia* and *Julbernardia*) are >=22% of all species.<br>• BOE2:<br>diametric distribution presents inverted J Curve Apparent. | • Lack of benchmarks for some indicators. |

| Metric name | General description | Indicators | Applicability of indicators to Miombo in Mozambique | Adaptation to Miombo woodlands in Mozambique | Limitation for application in Mozambique |
|---|---|---|---|---|---|
| England (BOE) | **Distinctiveness**, **Condition, Area of habitat in hectares**. | • **Condition**: species richness, cover, presence of specific habitat structures, anthropologic and natural degradation level, ecological succession, adjacent land uses/types, trees health condition, etc. • **Area of habitat (ha)** | which are "degraded" versions of others, together with expert-based rankings (distinctiveness & multipliers), and then case-by-case judgments by ecologists (condition). However, with adjustments and reduction of complexity it can be applicable. | • BOE3: Recruitment of Miombo spp. (Saplings with 5cm<= DBH<10cm) greater than 150/ha. • BOE4: standing trees of Miombo indicator species of dbh>40cn are than 0.75% standing trees >40cm. • BOE5: Less than 3% of land cover by agricultural and other anthropogenic operations. (Annex II). | |
| Germany's Biotope Valuation (BV) | The method consists in building lists of biotopes types (types of land use) at local level and ascribing score values to them based on indicators. | Eight ecological criteria: • **Internal features**: maturity, unaffected state, diversity of the layer structure, diversity of species. • **External features**: rarity of biotopes, rarity of the biotope species, | Applicable with appropriate adjustments, but external features indicators are difficult/complex to measure in Miombo. | • C1. maturity of the Miombo: basal area(m2/ha) distribution. • C2. unaffected state of the Miombo: % of area affected by human activities. • C3. diversity of the layer structure: diametric distribution with an inverted-j shape. • C4. diversity of species: % of Miombo indicator species. • C5. rarity of Miombo (based on experts' judgment). | • Lack of benchmarks for some indicators. • Limited number of experts for rarity judgment. |

| Metric name | General description | Indicators | Applicability of indicators to Miombo in Mozambique | Adaptation to Miombo woodlands in Mozambique | Limitation for application in Mozambique |
|---|---|---|---|---|---|
| | | sensitivity of biotopes, threat to the number and quality of biotopes. | | • C6. rarity of<br>The Miombo species (based on % of Miombo species).<br>• C7.<br>sensitivity of Miombo (based on Miombo self-regeneration).<br>• C8. threat to<br>the extent and quality of Miombo (based on general deforestation rates).<br>(Annex II). | |
| Forest Integrity Assessment Tool (FIAT) | Use field forms to assess forest condition in 2 different groups: structure and composition, and Impacts and Threats. | • Structure and Composition: 20 indicators.<br>• Impacts and threats: 15 indicators.<br>• Key Habitats<br>• Key Species. | Applicable but with limitation | Structure and Composition:<br>C1: Presence of naturally fallen large trees (DBH≥30cm)<br>C2: 4% of very large trees (DBH≥30cm)<br>C3: 32 % medium size trees (10cm<DBH<29,9 cm)<br>C4:>47% of saplings (5cm<DAP<9,9cm)<br>C5: grass cover<br>C6: woody biomass<br>C7: medium/large trees with height>8m<br>C8: canopy cover<br>C9: Relative density of Miombo indicator species<br><br>Impacts and Threats:<br>I1: presence of invasive/exotic species<br>I2: Presence of large trees of species<br>I3: Presence of small to medium trees of species<br>I4: Evidences of illegal hunting | • Too many indicators;<br>• Some complex to measure in the field<br>• Lack of benchmarks for some indicators.<br>• Limited number of skilled field operators<br>• Not all Indicators are meaningful to measure site condition. |

| Metric name | General description | Indicators | Applicability of indicators to Miombo in Mozambique | Adaptation to Miombo woodlands in Mozambique | Limitation for application in Mozambique |
|---|---|---|---|---|---|
| | | | | I5: Evidence of logging, agricultural use, pasture,<br>I6: Evidence of solid waste<br>I7: Distance to access roads or rivers <2km<br>I8: Evidence of t species with conservation value<br>I9: Evidence of critical habitats<br>I10: % of fire indicator species<br><br>Key Habitats:<br>Presence of dambos<br>Presence of riverine forests<br>presence of lagoon or other wetland<br>Presence of steep slopes covered with forest<br><br>Species with conservation value: assuming 3% of total richness has species with conservation value.<br><br>(Annex II). | |
| Madagascar Ambatovy mine metric | The metric used in the Madagascar Ambatovy mine project to assess the condition of forest types ('zonal', 'transitional' and 'zonal') comprises | • Habitat quality index: number of trees per hectare, the number of species of tree per hectare, the basal area, and the average height of the tree canopy cover, each weighted | Applicable | • Habitat Quality-Ambatovy (HQ):<br>HQ1: # of trees => 5cm in dbh;<br>HQ2: % of Miombo indicator species;<br>HQ3: basal area (m2/ha);<br>HQ4: height (m). | • Limited to only structural aspects. |

| Metric name | General description | Indicators | Applicability of indicators to Miombo in Mozambique | Adaptation to Miombo woodlands in Mozambique | Limitation for application in Mozambique |
|---|---|---|---|---|---|
| | structural (**habitat)** and **species** indicators. | equally to come up with an overall quality score<br>• Species indicator uses the diversity of species of concern. | | | |

### 3.3. Testing methodologies with existing field data

In order to test the above selected methodologies we used two datasets archived at the Faculty of Agronomy and Forest Engineering (FAE) from the Eduardo Mondlane University (UEM) in Maputo and representing two different Miombo types and ecological conditions. The first, was collected during the years 2017 - 2018 in 24 1-ha plots located in Niassa National Reserve (NNR) in northern Mozambique. The site is the largest protected area in the country and presents one of the last remnants of undisturbed sub-humid Miombo. The second dataset was collected in 2017 in the Pomene National Reserve (PNR) in Inhambane Province in southern Mozambique. The area represents a dry Miombo with some coastal elements and 3 apparent different ecological states (dense Miombo, open Miombo and degraded Miombo). These ecological states were identified in the report from FAEF (FAEF 2017) and corresponded to variations in canopy cover, which were translated in varied structure and composition. Dense Miombo and open Miombo correspond to undisturbed states and the differences in canopy cover are likely related to variations in soil composition and location (open Miombo is closer to the coast and dense is inland).

As a result, for the present work we have reclassified each plot into one of the three categories using the following thresholds of canopy cover: >50% (Dense undisturbed Miombo); 30%-50% (Open undisturbed Miombo) and <30% (Degraded Miombo). It is important to clarify that the miombo is not considered a forest itself and given its heterogeneity across the country its canopy cover is sometimes under 30% but it can still in a good ecological condition. However, the threshold used in this study is aligned with the national forest definition (under the REDD+ framework), which uses 30% as the cut off level. This is justified by the fact that most miombo types in Mozambique are under the category of forests according to the national forest classification scheme (DINAF, 2018). In the case of the study area, the cut off level was confirmed in the field as reflected in section 4.1. Having used canopy cover as a classification metric, it was then removed from the indicators for quality condition. The data was collected following the national forest inventory methodology in which a 1-ha cluster composed of 4 plots of 20x50m corresponding to 0.4ha.

Each dataset was compiled to reflect the rest of the indicators referred in Table 1 and then used to test the selected methodologies. At this stage the test was conducted as a preliminary analysis of the practicability of the metric, their ability to differentiate categories of Miombo and respective conditions as well as the feasibility of the indicators.

This initial testing was presented and discussed at a technical meeting with national experts from different sectors (government, private and academia). In this meeting we analyzed the level of complexity of each metric in terms of data collection and analysis and agreed that the VQM-HH and BV metric have a high level of complexity for the Mozambican context, especially in terms of technical capacity and EIA timelines. This left the team with

BOE and FIAT to apply the final testing procedure. The report from the technical meeting is presented in Annex III.

During the process part of the team had the opportunity to visit the biodiversity offsetting system Madagascar, which is implementing an adaptation for the VQM method simplified to use only structural parameters. Based on this visit, the team included also this method in the analysis. It was also decided by the team to retain the BV methodology as well, as after reflection it was felt that the objections raised in the technical meeting were reasonably easy to overcome by further modifying the methodology to the national context.

After the final test the results were presented in a national workshop in which the participants were able to conduct some practical exercises with the selected Ambatovy metric. In the workshop, discussions focused on the fact that the miombo woodland ecosystem is affected by and influenced by fauna, fire, human beings, as well as specific biophysical aspects such as soil composition and precipitation levels. Other elements such as the presence of endemic species or the provision of ecosystem services were also considered to be important.

However, the fact that all these aspects are important does not mean that they all must be included in the current metric, which is designed to focus on habitat condition. Including all these different and disparate elements into one single composite quality Index is not recommended. Recalling the fact that this index is only one step in determining the size of the biodiversity offset area needed, we should be careful of including certain aspects, particularly fauna, rare/endemic species, and ecosystem services, which will need to be dealt with separately in the overall offset scheme chosen.

Fauna must be dealt with separately from ecosystem/habitat for offset schemes. Particularly in a place like Mozambique, where much of the fauna of conservation interest is also of interest for local population use and consumption, the presence or absence of that fauna must be assessed separately. As an example, the Ambatovy mine also considers fauna totally separately. In their case, they use an area of occupancy metric to determine how much habitat is needed and is being used by those specific species of interest. This allows one to consider not only the base quality of the habitat to the species, but also using into consideration what size of populations are being affected and how those populations use that habitat. When we consider that rare or key species may range from large mammals such as elephants to birds that may migrate over thousands of kilometers to endemic reptiles or amphibians that may occupy only a specific niche in the habitat, we can see that trying to include all of these elements into a larger composite metric for habitat quality is bound to inadequate.

Specific endemic flora species must also be dealt with separately. If the impact assessment determines that there are specific endemics or near endemics in the impact area, these need to be assessed separately and individual plans made for their protection and or offsetting. Again, simple inclusion in a habitat condition metrics will not be enough to ensure their protection, and therefore, since they must be dealt with has a separate and specific component of the biodiversity offset, there is no added value to placing them inside the larger and more generic habitat condition Index.

So while an argument can be made that for example the number of endemic species or the presence of keystone fauna species is an element of habitat condition, we therefore recommend that these are not included in this specific metric.

With regard to ecosystem services, these too must be assessed and compensated for separately. Most ecosystem services such as water, food, building materials, or those used as economic resources, will be directly benefitting the local communities around the impact site. Given the fact that the offset site is likely to be too far away for any of these services to be accessible by the affected people, special provisions must be made in all cases. This will generally be part of the social compensation program that project proponent must put in place. While it is a key part of the environmental and social impact assessment process to identify, itemize, and quantify these ecosystem services, this is not part of the habitat condition metric for offset purposes.

As for landscape features, such as rivers, wetlands, and miombo specific features such as dambos, while these were accounted for or at least recorded in the FITA methodology, they are not quantified in any of the others. There are some offset systems around the world that consider a specific and separate landscape component to the overall offsetting system, but this is neither universal nor easily integrated into the systems we have assessed here.

The one additional factor that we feel however must be considered in miombo condition for Mozambique is the presence of human intervention and impact. In Mozambique, agricultural conversion of forest is responsible for 2/3 of annual deforestation, and anthropogenic use for charcoal, and firewood account for another 8% as well (CEAGRE/WINROCK, 2015). While it is likely that a large human presence will already have been registered in the number of trees, their size, and their species composition, because of its importance human impact/threat should be incorporated into any metric that is recommended.

These aspects could be incorporated into several of the methodologies analysed, but we have chosen to add to the Ambatovy model as an additional factor. This combined metric therefore evaluates structural components, i.e. tree density, tree height, species composition, and basal area, as well as the effect of human influence. This results in a condition score that captures the key components identified together by experts and stakeholders, but excludes those aspects that must be done separately in a complementary way to determine the final overall offset makeup.

As a result, we changed the Ambatovy metric to include the element of human intervention; the new metric called MIOMBO is explained in detail in Annex II.

### 3.4. Field data collection and analysis

In the following step, the team conducted a fieldwork in PNR with the intention of expanding the dataset used in the preliminary analysis and gather representative data for the area. As referred above the field site is one of the protected areas in the country and is located in Inhambane Province, southern Mozambique (Figure 3). NNR was left out of this final test given the limited dataset (not completely representative of the area) and the fact that it does not include categories of Miombo condition as well as the fact field work is limited by its low accessibility.


**Figure 3: Geographic Location of Pomene National Reserve, Inhambane Province Southern Mozambique.**

As observed in Figure 4, Miombo in PNR occurs along the coastline and as a result the vegetation has several coastal elements including tree species composition, low canopy cover and height among others. As discussed in the technical meeting, this is not likely the best representation of Miombo in Mozambique given the influence from the coast. However, due to budget limitations we still carried out the study in this area considering that it presents 3 good representations of ecological conditions (undisturbed dense, undisturbed open and degraded) and it is easily accessible. In order to minimize the influence of coastal elements, we excluded Miombo areas that were <5km to the coast (south portion of Figure 4).

Using the criteria of Miombo location we conducted a stratified-random allocation of clusters (Figure 4) with ecological state (dense, open and degraded) as the strata. In each cluster, vegetation data was collected in June 2019: tree and grass species identification, dbh, height, canopy cover and grass cover. The data was combined with the 2017 dataset and analysed to describe the ecological condition of the three strata in terms of structure (Section 4.1): diametric distribution, average height, basal area and canopy cover; and composition (Section 4.1): Importance Value Index (IVI = %basal area + % n/ha+% frequency). The dataset was also used to further test the metrics for final selection.

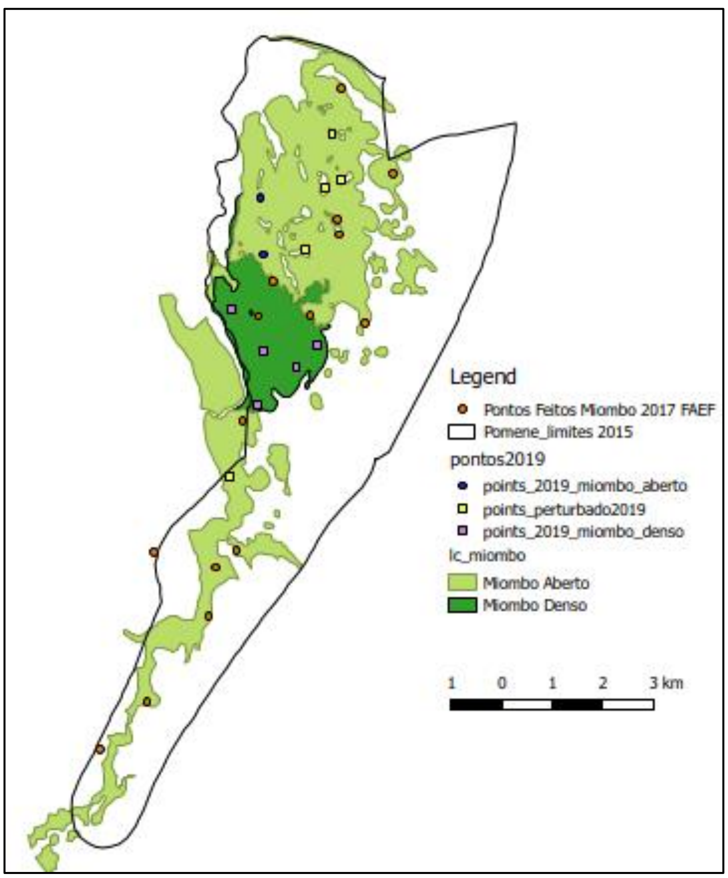



**Figure 4: Miombo woodlands distribution with the Stratified random-sampling distribution in Pomene National Reserve.**

### 3.5. Metric comparison and sensitivity analysis

In the final stage we tested the metrics (BOE, BV, Ambatovy, FIAT and MIOMBO) using the field data from PNR and refined the calculation of the scores based on the expanded dataset. Each metric was analysed in terms of its ability to separate the ecological condition of Miombo by using the Kruskal-Wallis statistical test and t-test for paired comparisons at the 5% level of significance.

A sensitivity analysis was conducted for the selected MIOMBO metric, which was the approach that better separated the three Miombo categories. For this matter, we used the method One At a Time (OaT), which basically checks the ability of the metric to differentiate the three Miombo categories when one individual indicator is removed. After removal of individual indicators, the average scores were calculated and the statistical analysis conducted based on the new average.

## 4. Results and Discussion

### 4.1. Structure and composition of Miombo woodlands in Pomene National Reserve

The Miombo woodland in PNR is part of the dry Miombo category with coastal element namely: sand dune soils and presence of coastal forest species (e.g. Balanites maughamii). In general the three Miombo categories are dominated by Miombo indicator species (Julbernardia globiflora and Brachystegia spiciformis; Table 5). However, in the open and degraded states Miombo indicators species are associated with other species such as: Anacardium occidentale (IVI=46.88); an exotic species-cashew nut tree), Ozoroa spp (IVI=24.38), Sclerocarya birrea (IVI=12.15) and Strychnos madagascariensis (IVI=10.04) in the degraded Miombo and Anacardium occidentale (IVI=20.49), Hyphaene coriacea (IVI=15.90), S. madagascariensis (IVI=13.41) and Sclerocarya birrea (IVI=12.85) in the open Miombo.

It is important to refer that the most dominant species in open and degraded Miombo provide resources (fruits, medicine, fiber) for local communities. This situation is very common in agricultural fields or areas that have been abandoned after cultivation, in which some tree species are left in fields for nutritional and/or medicinal purposes. A. occidentale (cashew tree) is an exotic tree that is planted for commercial uses and the fact that it is dominant in degraded Miombo is an indicator of the disturbed condition of these areas. It is also worthwhile mentioning the presence of Balanites maughamii in both open and degraded Miombo, a typical species of coastal forests.

**Table 4: Importance Value Index (IVI) of tree species per type of Miombo in**

| Indicators | Miombo Category | | | |
|---|---|---|---|---|
| | Dense Miombo | Open Miombo | Degraded Miombo | Miombo Benchmarks |
| Tree canopy cover (%) | 73.13 | 44.29 | 15.11 | 30-59 (Open) >60 (Dense) |
| Tree density (trees/ha) | 321.88 | 218.57 | 198.89 | 400-500 |
| Recruitment (N/ha; Saplings with 5≤DBH<10cm) | 391.56 | 112.14 | 123.61 | - |
| Intermediate trees (N/ha;10≤DBH<30cm) | 144.38 | 103.57 | 73.06 | - |
| Number of large trees (N/ha; 30≤DBH<40 cm) | 3.75 | 2.14 | 1.39 | - |
| Woody biomass (Mg/ha) | 25.85 | 13.97 | 13.53 | 62.24 |
| Basal area (m2/ha) | 4.16 | 2.18 | 2.03 | 8-10 |
| Height (m) | 4.67 | 4.81 | 4.12 | 8-12 |

**Pomene National Reserve (Bold numbers highlight the most important species per Miombo type).**

| | Importance Value Index (IVI) | | |
|---|---|---|---|
| | Dense undisturbed Miombo | Open undisturbed Miombo | Degraded Miombo |
| *Julbernardia globiflora* | **138.79** | **117.38** | **41.94** |
| *Brachystegia spiciformis* | **59.75** | **57.23** | **110.55** |
| *Ozoroa sp.* | 5.52 | 0.00 | **24.38** |
| *Garcinia livingstonei* | 5.49 | 3.17 | 4.42 |
| *Diospyrus rotundifolia* | **11.23** | **9.68** | 0.00 |
| *Strychnos spinosa* | **7.54** | **10.60** | **8.23** |
| *Sclerocarya birrea* | 0.00 | **12.85** | **12.15** |
| *Hyphaene coriacea* | 3.76 | **15.90** | 6.93 |
| *Strychnos madagascariensis* | **7.11** | **13.41** | **10.04** |
| *Anacardium occidentale* | 4.30 | **20.49** | **46.88** |
| *Olax dissitiflora* | 5.38 | 7.35 | 2.71 |
| *Trichillia emetica* | 4.09 | **11.16** | **7.51** |
| *Balanites maughami* | 0 | **9.76** | 3.59 |

**Table 5 presents the structural parameters for the three Miombo categories in comparison to the benchmarks. The table reveals that in fact the dense undisturbed Miombo is closer to the benchmarks, but it is**

**still below the benchmarks for some parameters, which is likely due to the fact that it is a coastal Miombo. The diametric distribution reveals that dense Miombo has a typical inverted-j shape curve of a natural undisturbed**

| Indicators | Miombo Category | | | |
|---|---|---|---|---|
| | Dense Miombo | Open Miombo | Degraded Miombo | Miombo Benchmarks |
| Tree canopy cover (%) | 73.13 | 44.29 | 15.11 | 30-59 (Open) >60 (Dense) |
| Tree density (trees/ha) | 321.88 | 218.57 | 198.89 | 400-500 |
| Recruitment (N/ha; Saplings with 5≤DBH<10cm) | 391.56 | 112.14 | 123.61 | - |
| Intermediate trees (N/ha;10≤DBH<30cm) | 144.38 | 103.57 | 73.06 | - |
| Number of large trees (N/ha; 30≤DBH<40 cm) | 3.75 | 2.14 | 1.39 | - |
| Woody biomass (Mg/ha) | 25.85 | 13.97 | 13.53 | 62.24 |
| Basal area (m2/ha) | 4.16 | 2.18 | 2.03 | 8-10 |
| Height (m) | 4.67 | 4.81 | 4.12 | 8-12 |

**forest. This curve reveals a stable ecological condition in which the presence of a large number of small trees will allow adult class reposition if logging occurs (Lamprecht, 1990). On the other hand, open and degraded Miombo have similar distribution which deviates from the typical inverted J-curve (**

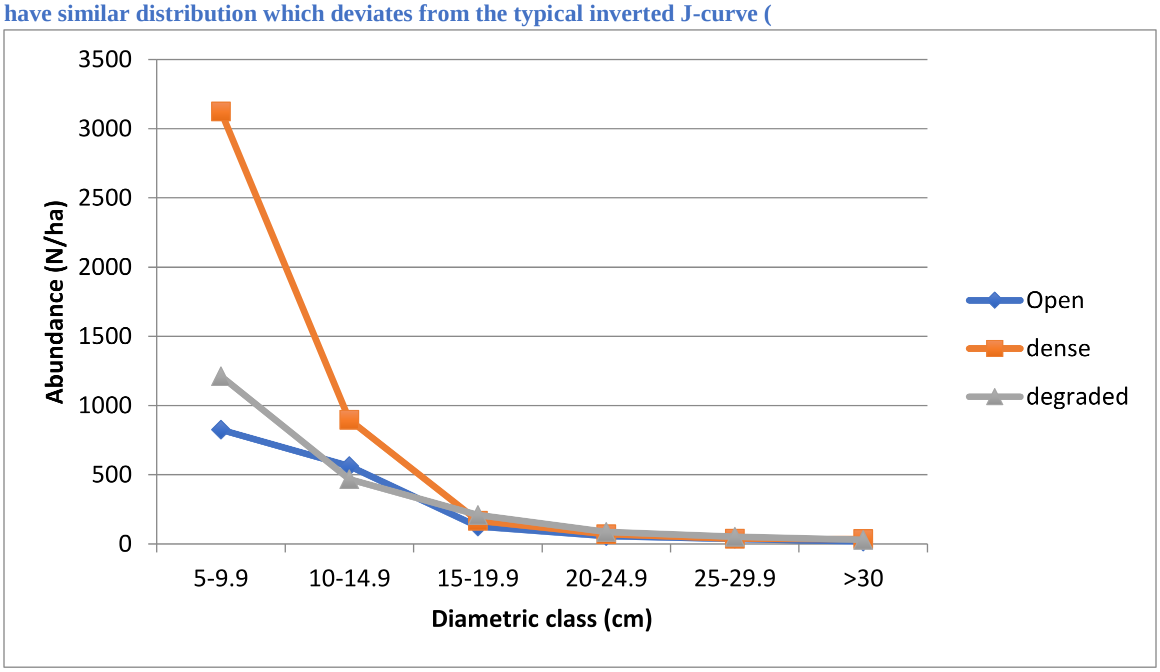



Figure 5). Although small size trees are still more abundant than the large size trees, the proportional decrease of the tree numbers per size may not be quite enough for ecosystem resiliency.

**Table 5: Structural parameters of Miombo woodlands in Pomene National Reserve.**

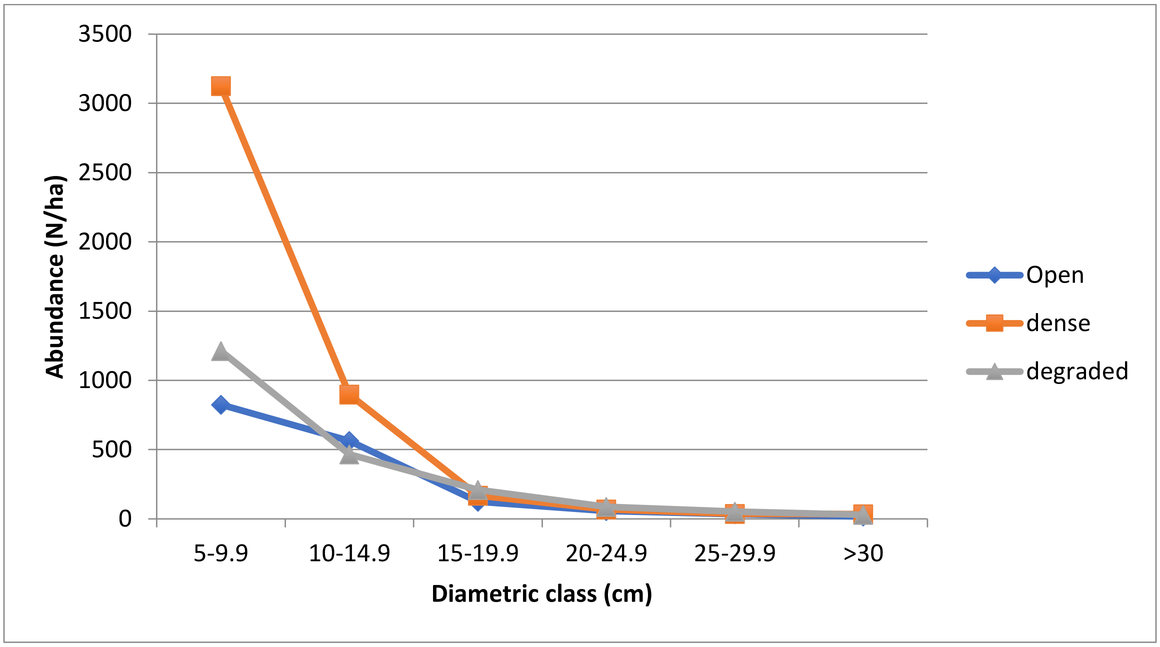
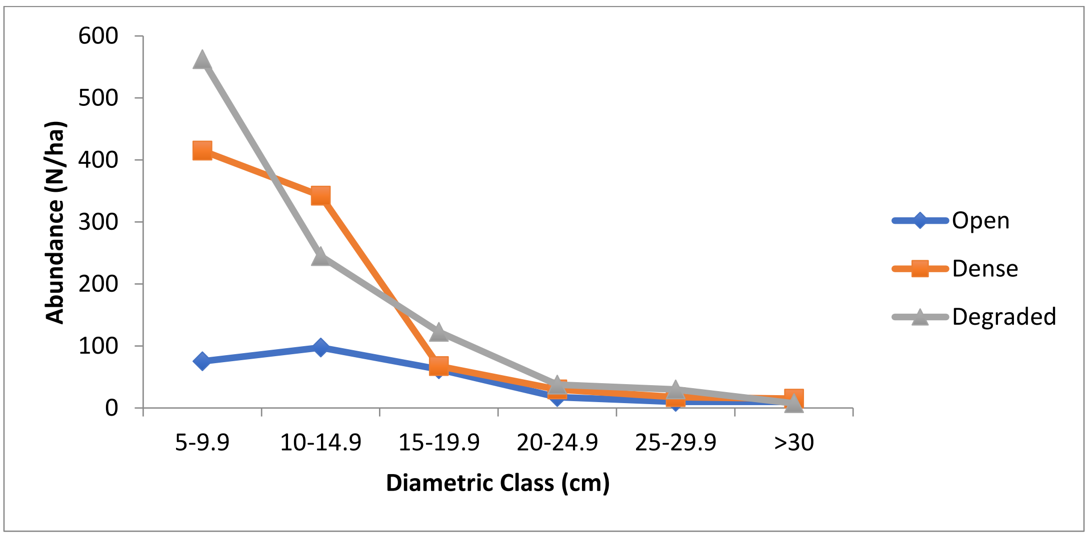



**Figure 5: Overall diametric distribution of adult species in Pomene National Reserve.**

The structural parameters for the Miombo indicator species indicate that they do not differ among the three Miombo categories in terms of average height, dbh and basal area, except for *J. globiflora* which have a significantly higher basal area in dense undisturbed Miombo (Table 7). The diametric distributions reveals that in fact *B. spiciformis* is well distributed in all three woodlands categories, but *J. globiflora* deviates from the inverted j-shape curve in open undisturbed and degraded Miombo (Figure 7). *B. spiciformis* also deviates from the inverted J-shape curve for open Miombo. The presence of Miombo indicator species in the degraded Miombo is a surprise but it can result from the fact that these species are also resource species for local communities. On the other hand, they are very resilient and quickly regenerate once the disturbances such as agriculture are removed. However, *J. globiflora* may be at risk in open undisturbed and degraded Miombo categories, which is likely, a consequence of this species being preferred over *B. spiciformis* for fibre and other uses.

**Table 6: Summary of descriptive statistics of height, diameter at breast height (DBH) and Total basal area for *Julbernardia globiflora* and *Brachystegia spiciformis* in Pomene National Reserve (same letters after the numbers indicates non-statistical differences by Analysis of Variance at 5% significance level).**

| Miombo category | *Julbernardia globiflora* | | | *Brachystegia spiciformis* | | |
|---|---|---|---|---|---|---|
| | **Height in m (standard deviation)** | **DBH in cm (standard deviation)** | **Basal area in m2/ha (standard deviation)** | **Height in m (standard deviation)** | **DBH in cm (standard deviation)** | **Basal area in m2/ha (standard deviation)** |
| Dense | 4.08 (0.86)a | 8.25 (3.43)a | 7.75 (0.02)b | 4.81 (2.19)a | 10.83 (5.83)a | 3.86 (0.04)a |
| Open | 4.44 (1,78)a | 8.71 (3.18)a | 2.68 (0.02)a | 4.85 (1.74)a | 11.94 (6.85)a | 2.04 (0.04)a |
| Degraded | 3.94 (1.20)a | 10.14 (6.86)a | 1.39 (0.05)a | 4.66 (1.15)a | 10.63 (5.5.3)a | 4.53 (0.03)a |



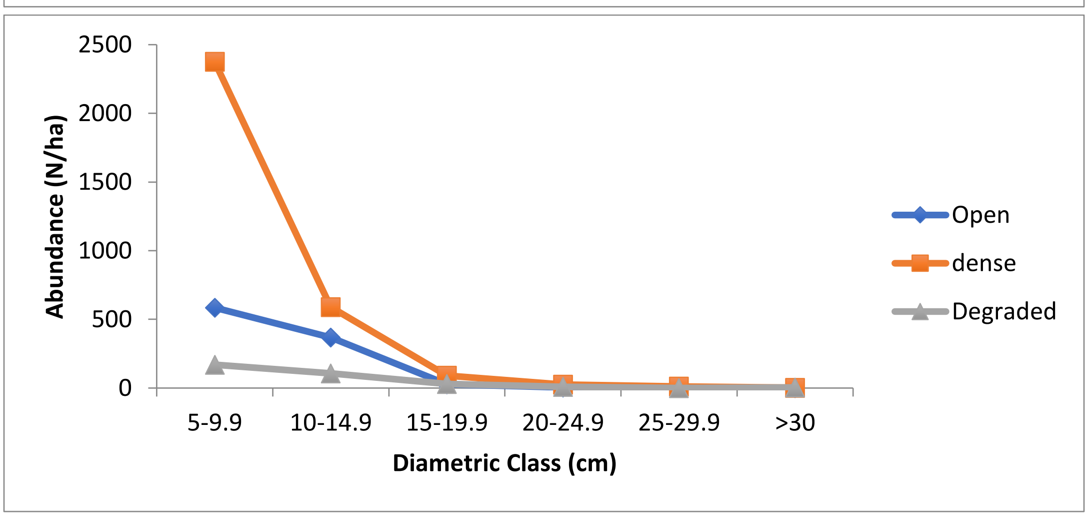



**Figure 6: Diametric distribution of Miombo indicator species (*Brachystegia spiciformis* on the top panel and *Julbernardia globiflora* on the bottom) in Pomene National Reserve.**

While the inverse J-Curve is an important metric for analysis of the forest plot, quantifying it inside a general quality metric is difficult due to a lack of the clearly and generally accepted descriptive formula. As a result it can be only be included as a binary indicator (yes/no), which makes it suitable only for some of the methods analysed.

## 4.2. Metrics comparison and selection

### 4.2.1. Summary of the metrics tested

In this section we present a summary of the 5 metrics and their ability to separate the dense undisturbed, open undisturbed and degraded Miombo categories. This was determined by using a parametric Kruskal-Wallis test and a pairwise Wilcox test at 5% level of significance. In general the MIOMBO metric was able to separate the dense undisturbed from the degraded Miombo categories quite well, while BV, BOE, Ambatovy and FIAT produced similar results for the three Miombo types (Tables 8-12; for detailed information about the methods check the excel file attached to this document).

The BV metric uses a combination of 4 important indicators (Table 8): maturity given by the basal area (C1), unaffected state measured by the presence of human activities associated with the time since abandonment (C2), the diversity of the layer structure given by the diametric distribution (C3) and the diversity of species (C4), which is measured by the percentage of Miombo indicator species (see Annex II for detailed description of this metric). Apart from being key variables in defining Miombo condition almost all of these indicators are easy to measure in the field and are part of the standard measures in any forest inventory. However, C2 is subjective as it measures the % of area affected by human activities conjugated with time since abandonment. These are not possible to objectively measure in the field. For this particular method, we eliminated the original indicators of rarity and sensitivity as Miombo is not particular rare in the country and is considered a resilient ecosystem. Apart from that, rarity and sensitivity are not so easy to measure and depend on the specialist ability to decide. While these aspects could be incorporated into a national metric as part of a larger and more participatory ecosystem assessment, such as that currently being carried out in the context of KBAs, they are beyond the scope of the present report and so it has not been possible to consider them here. In any event, since these aspects are related to the larger ecosystem (in this case Miombo), for the present exercise they would be unchanged across the habitat types and therefore have no influence on the final score.

This metric was not able to separate the three Miombo categories, which is likely due to the fact that BV places field values in categories (1-6). The immediate result is that if a parameter does not differ significantly among the three Miombo categories they all fall in the same class (e.g. C1 measures by basal area). In fact, as seen in Section 4.1 the three Miombo types are not significantly different for most of the indicators used in this metric.

**Table 7: Summary of BV scores for Pomene National Reserve (same letters after the numbers indicates non-statistical differences by Kruskal-Wallis at 5% significance level; chi-squared = 4.4286, df = 2, p-value = 0.1092).**

| | BV Scores | | | | |
|---|---|---|---|---|---|
| **Miombo category** | **C1 (Maturity of Miombo) (Min:1-Max:6)** | **C2 (Unaffected state) (Min:1-Max:6)** | **C3 (Diversity of the layer structure) (Min:1- Max:6)** | **C4 (Diversity of species) (Min:1-Max:6)** | **BV Quality Score (C1+C2+C3+C4)** |
| Dense Miombo | 2.88 | 5.13 | 2.38 | 5.38 | **15.75a** |
| Open Miombo | 2.00 | 3.71 | 2.57 | 6.00 | **14.29a** |
| Degraded Miombo | 1.89 | 2.44 | 1.78 | 5.44 | **11.56a** |

The BOE metric combines also key important indicators of Miombo condition (Table 9): dominance of Miombo indicator species (BOE-1), diametric distribution (BOE-2), recruitment (BOE-3), presence of large trees (BOE-4), state of unaffected Miombo (BOE-5) measured as the percentage of the area covered by human activities. As referred for BV, these are also easily measured in the field and follow standard methods, but for the human interference there are no benchmarks and it can only be assessed subjectively. This metric gives emphasis to recruitment and presence of large trees instead of maturity of the woodlands as BV metric does. This is an advantage from the point of view of providing separated information for young and adult trees. However, since this information is captured in the diametric distribution, this can be seen as redundant data. On the other side, basal area is a key indicator of woodland maturity, which is missing in this metric.

As referred for the BV metric, the BOE class assignation is based on a Yes (1) or No (0) response, which again eliminates the possibility of objectively comparing different categories of Miombo if the indicators are not significantly different as it happens in PNR. Since the objective of this methodology is to simplify the classification of quality onto only a three-point scale, it clearly cannot be expected to be as fine an instrument as some of the other methodologies analysed.

**Table 8: Summary of BOE scores for Pomene National Reserve (same letter after the numbers indicate non-statistical differences by Kruskal-Wallis at 5% significance level; chi-squared = 5.8235, df = 2, p-value = 0.05438).**

| | BOE Scores | | | | | | |
|---|---|---|---|---|---|---|---|
| **Miombo category** | **BOE-1 (Miombo indicatorspecies are dominant)** | **BOE-2 (Inverted j-curve apparent)** | **BOE-3 (Recruitment of Miombo species)** | **BOE-4 (Presence of large trees)** | **BOE-5 (Stated of unaffected Miombo)** | **BOE Score (BOE1+BOE2+BPE3+BOE4+BOE5** | **Category** |
| **Dense Miombo** | **1.0** | **0.00** | **0.14** | **0.29** | **0.57** | **2.00a** | **B** |
| **Open Miombo** | **0.88** | **0.13** | **0.50** | **0.25** | **1** | **2.753a** | **B** |
| **Degraded Miombo** | **0.89** | **0.00** | **0.33** | **0.11** | **0.22** | **1.56a** | **C** |

The FIAT metric (

Table 9) was initially considered as one of the best metrics given the amount of indicators that provide general information about the woodland condition, apart that it also combines information about other elements of the system such as impacts and risks, key habitats and species with conservation value. However, FIAT has the same limitation as BV and BOE in which the assessment is quantitatively through a yes or no response (see Annex II for data description) and the use of some volatile (e.g. grass and mushrooms) make it less attractive than the other metrics. In addition, the Kruskal-Wallis test revealed that FIAT was not able to separate open from dense undisturbed Miombo, which is desirable in this area for the reasons referred above (Table 10).

**Table 9: Summary of FIAT scores for Pomene National Reserve (same letter after the numbers indicate non-statistical differences by Kruskal-Wallis at 5% significance level, chi-squared = 10.771, df = 2, p-value = 0.004584).**

| INDICATOR | Miombo Category | | |
|---|---|---|---|
| | Dense undisturbed Miombo | Open undisturbed Miombo | Degraded Miombo |
| **STRUCTURE AND COMPOSITION** | | | |
| C1: Presence of naturally fallen large trees; DBH≥30cm | 1 | 1 | 1 |
| C2: > 4% of very large trees (DBH≥30cm) | 0.25 | 0.14 | 0 |
| C3: >32% of medium size trees (10cm<DBH<29,9 cm) | 0.50 | 0.72 | 0.56 |
| C4: :>47% of saplings (5cm<DAP<9,9cm) | 0.50 | 0.57 | 0.56 |
| C5: Presence of grass cover | 0.63 | 1 | 0.78 |
| C6: =>50% of woody biomass benchmark (62.24 Mg/ha | 0.38 | 0.14 | 0.11 |
| C7: >50% of medium/large trees with height>8m | 1 | 1 | 1 |
| C8: 30-60% of canopy cover | 1 | 1 | 0 |
| C9: >22% of relative density of Miombo indicator species | 0.88 | 1 | 0.89 |
| **Average structure and composition** | **6.13** | **6.57** | **4.78** |
| **% of yes response in C** | **68** | **73** | **53** |
| **IMPACTS AND RISKS** | | | |
| I1: Presence of invasive/exotic species | 1 | 0.57 | 0.33 |
| I2: Presence of large trees of commercial species | 0 | 0 | 0 |
| I3: Evidences of illegal hunting | 1 | 1 | 1 |
| I4: Evidence of logging, agricultural use, pasture, | 1 | 0.57 | 0.22 |
| I5: Evidence of solid waste | 1 | 1 | 1 |
| I6: Distance to access roads or rivers <2km | 1 | 0.57 | 0.22 |
| I7: Presence of species with conservation value | 1 | 1 | 1 |
| I8: Evidence of critical habitats | 1 | 1 | 1 |
| I9: Occurrence of annual fire | 0 | 0 | 0 |
| **Average Impacts and Risks** | **7.0** | **5.71** | **4.78** |
| **% of No responses** | **78.0** | **63.0** | **53.0** |
| **CRITICAL HABITATS** | | | |
| KH1: Presence of dambos | 1 | 1 | 1 |
| KH2: Presence of riverine forests | 1 | 1 | 1 |
| KH3: presence of lagoon or other wetland | 0 | 0 | 0 |
| KH4: Presence of steep slopes covered with forest | 0 | 0 | 0 |
| **Average Critical habitats** | **2** | **2** | **2** |
| **% of yes Response** | **50** | **50** | **50** |
| **Average total (%)** | **65.28a** | **62.17a** | **52.06b** |

BV, BOE and FIAT were excluded from the sensitivity analysis because they were not able to separate the three Miombo categories.

The original Ambatovy method is solely based on structural woody elements, and there is no provision for any rarity or threat aspects to be added. The index is made up of: the number of trees per hectare, the number of tree species per hectare, the basal area, and the average height of the tree canopy cover, each weighted equally to come up with an overall condition score. Each factor is rated as a percentage against an ideal benchmark, values for which were taken from an area close by the mind which was judged by a group of interested stakeholders as being of the highest quality in the area (BBOP, 2014).

In our version of the Ambatovy methodology we replaced the "number of species" by "% of indicator species" since the actual species composition of Miombo is not nearly as diverse as the Malagasy forest. We therefore, combined 4 indicators of structure and compositions (HQ; Table 11): Tree density above 5cm dbh (HQ1); Height of trees (Julbernardia and Brachystegia; HQ2), basal area (HQ3) and % of indicator species (HQ4). In the metric, these indicators are given as % of the benchmark for Miombo. These indicators are reasonably easily measured in the field with standard methodologies from the national forest inventory and are easily compared with benchmarks (either regional or defined for the area). For the current exercise we used the national forest inventory as the benchmarks.

The research team recognizes that when looked at from the wider national perspective, the lack of benchmarks could be seen as problematic. None of Mozambique's ecosystems have readily available and generally accepted benchmarks for the various aspects of structure and composition. This makes an absolute measurement difficult. For Miombo, we have used data from the country's Forest inventory as a reference point, but this is not an average and not an absolute benchmark. In practice this means that the MIOMBO methodology is actually measuring a relative score of condition, rather than absolute one. Yet this is not a significant disadvantage in applying the methodology to real world cases, as long as that limitation is clearly stated, one does not actually need to know the benchmarks to be able to compare different sites. As long as they have similar species composition, then the two sites structural elements can be compared to one another without needing to have an absolute benchmark.

**Table 10: Summary of Ambatovy scores for Pomene National Reserve (same letter after the numbers indicate non-statistical differences by Kruskal-Wallis at 5% significance level, chi-squared = 4.99, df = 2, p-value = 0.082).**

| Ambatovy Scores | Dense undisturbed Miombo | Open undisturbed Miombo | Degraded Miombo |
|---|---|---|---|
| nº trees >5cm (%) –HQA1 | 71.53 | 48.57 | 44.20 |
| % indicator sp. – HQA2 | 78.08 | 81.22 | 53.67 |
| Basal area (%) –HQA3 | 46.22 | 24.22 | 22.53 |
| Height of trees (%) – HQA4 | 46.72 | 48.11 | 41.18 |
| **Average score (%) HQA** | **60.64a** | **50.53a** | **40.39a** |

The adapted Ambatovy metric was the initially preferred metric and the one presented to stakeholders in August 2019 (Annex V). During the discussions, many references were made to the fact that the Miombo woodland ecosystem is affected by and influenced by fauna, fire, human beings, as well as specific biophysical aspects such as soil composition and precipitation levels. Other elements such as the presence of endemic species or the provision of ecosystem services were also considered to be important. However as explained above, not all of these elements should be included in the index of condition, but must be dealt with separately. Fauna, ecosystem services, and the presence of endemic species all fall into this category. The presence of invasives and exotics was not considered to be a critical aspect for this habitat, though this will not be true for some others.

Our final recommended metric – MIOMBO - therefore combines the Ambatovy structural approach with one more indicator that are key in defining Miombo ecological condition (Table 12): presence of human activity (agriculture, logging, charcoal etc.; HQ5). In the 2019 field protocols human impact was evaluated on a 4-point scale (1=<1%, 2=1-4.9%, 3= 5-50%, 4= >50%), which while not as discriminating a measurement as the percentages used for the other factors still allows for an adequate weighting inside the overall formula. As explained before, other factors of importance in determining Miombo ecosystem condition such as: presence of endemic species, landscape features and presence of fauna are not considered here because they will be considered separately in the final national offsetting system.

Table 12 indicates that the addition of this additional element (HQ5) to this metric adds value to the overall condition based only on structure and composition (HQ1-4) as the total score slightly increases, but it does not make much difference in terms of differentiating the three Miombo categories. The MIOMBO metric was only able to separate statistically the dense and degraded Miombo categories.

**Table 11: Summary of MIOMBO scores for Pomene National Reserve (same letter after the numbers indicate non-statistical differences by Kruskal-Wallis at 5% significance level, chi-squared = 8.3651, df = 2, p-value = 0.01526).**

| Indicator | Miombo Category | | |
|---|---|---|---|
| | Dense Miombo | Open Miombo | Degraded Miombo |
| **STRUCTURE AND COMPOSITION (HQ1-HQ4)** | | | |
| % of trees >5cm in dbh | 71.53 | 48.57 | 44.20 |
| % Height of trees | 46.72 | 48.11 | 41.48 |
| % basal area | 46.22 | 24.22 | 22.53 |
| % Miombo indicator species | 78.08 | 81.22 | 53.67 |
| **Average structure and composition** | **60.64** | **50.53** | **40.39** |
| **Presence of human activity (HQ5)** | | | |
| Average weighted presence human activity | 80 | 63 | 40 |
| **Average total (%): HQ1-HQ5** | **69a** | **56ab** | **416b** |
| **Ecological Condition** | **Good** | **Medium** | **Medium** |

### 4.2.2. Overall comparison

All the metrics analysed were placed on a common percentage-based axis for comparison purposes (Figure 8). Given the fact that all these methodologies seem to be able to distinguish reasonably clearly between the different types of miombo condition, it would seem appropriate to use any one of them. However, this appearance is somewhat misleading, as when analysed statistically (95% confidence level), BV and BOE were not able to separate the three categories while FIAT discovered a statistically significant difference between degraded Miombo and the other two types. While Open Miombo should not be interpreted as a semi-degraded state, halfway between dense and degraded Miombo, Dense and Open are different and it is important to be able to distinguish between them.

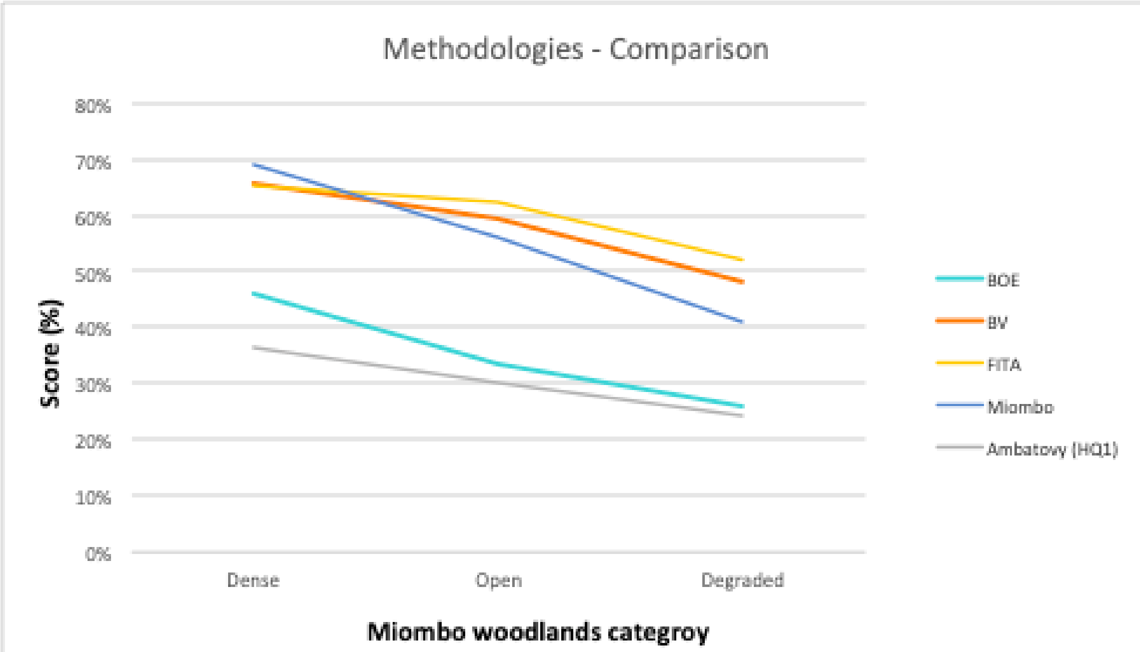



**Figure 7: Overall comparison among the metrics tested in this assignment.**

### 4.2.3. Sensitivity analysis

The sensitivity analysis was performed for the MIOMBO metric. The analysis was conducted by using the method OaT as described above. The results of the simulations are presented in Figures 8-11. The analysis reveal that in general the MIOMBO approach is stable in terms of its ability to separate the three Miombo categories, even when indicators are individually removed.

In terms of the significance of removing individual indicators the figures below show that the MIOMBO metric is more sensitive to removal of basal area (HQ3) and indicator species (HQ4). Removal of basal area significantly changed the average score and for Open undisturbed Miombo it implied a shift from medium to good ecological condition according to our categorization scheme. For the other 2 Miombo categories, even though the removal of basal area produced substantial modifications in final score, they are not enough to classify differently these two Miombos. In the case of indicator species removal, there was a significant decrease in average scores, but not enough to shift the Miombo category.

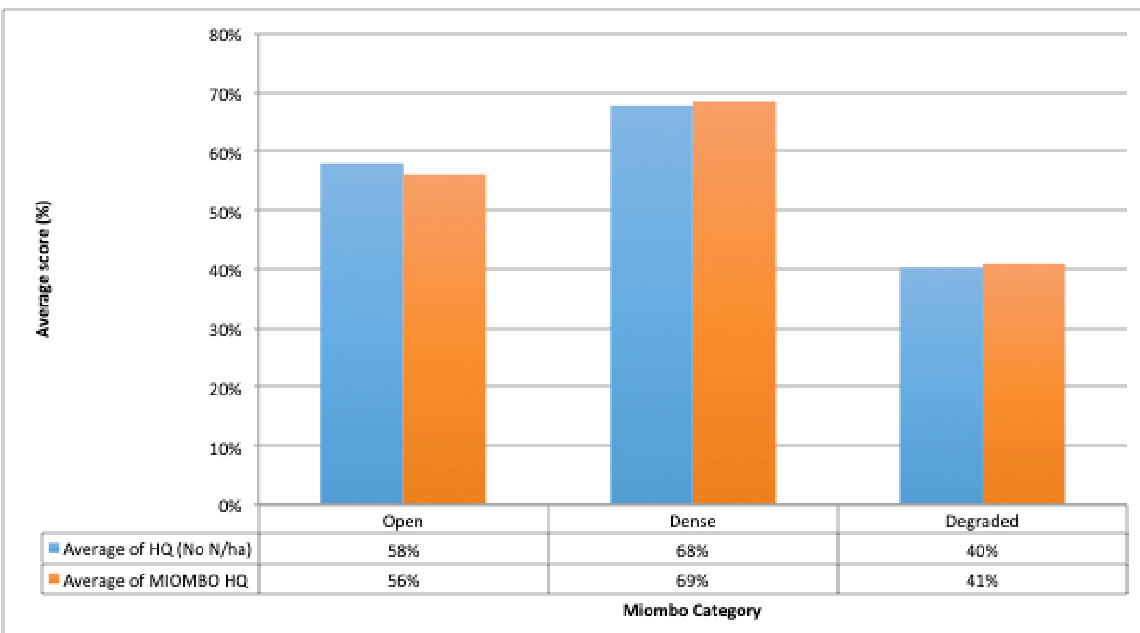



**Figure 8. Sensitivity of MIOMBO metric to tree density removal.**

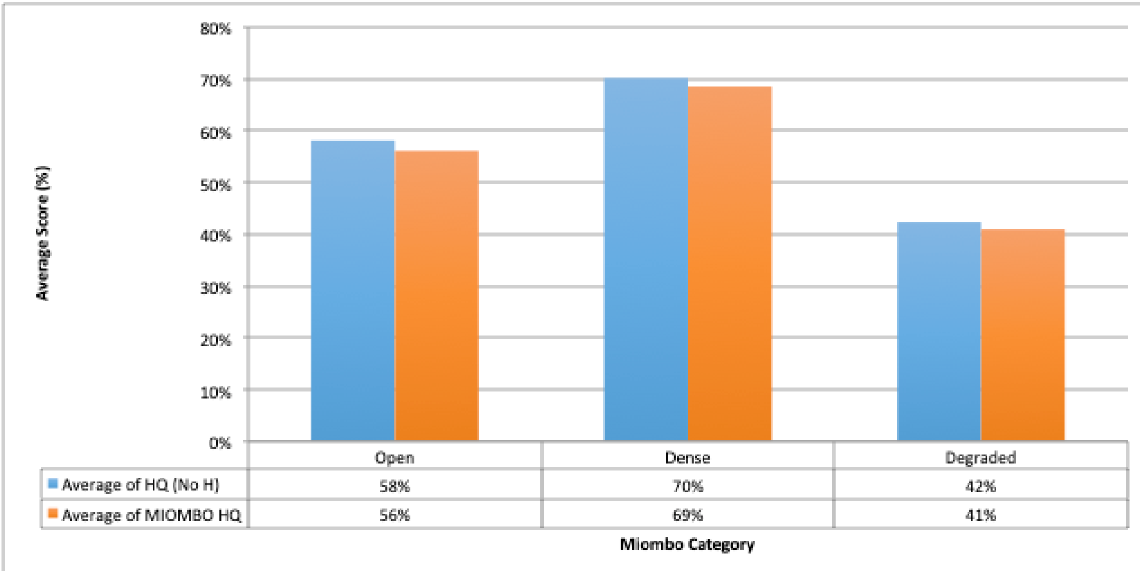



**Figure 9. Sensitivity of MIOMBO metric tree height removal.**

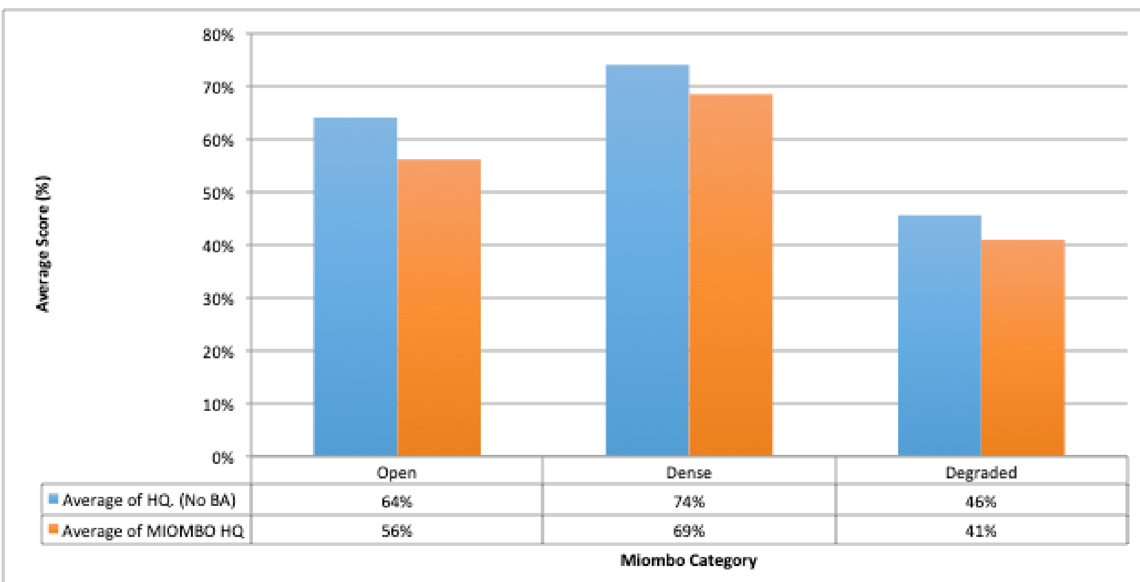



**Figure 10. Sensitivity of MIOMBO metric tree basal area removal.**

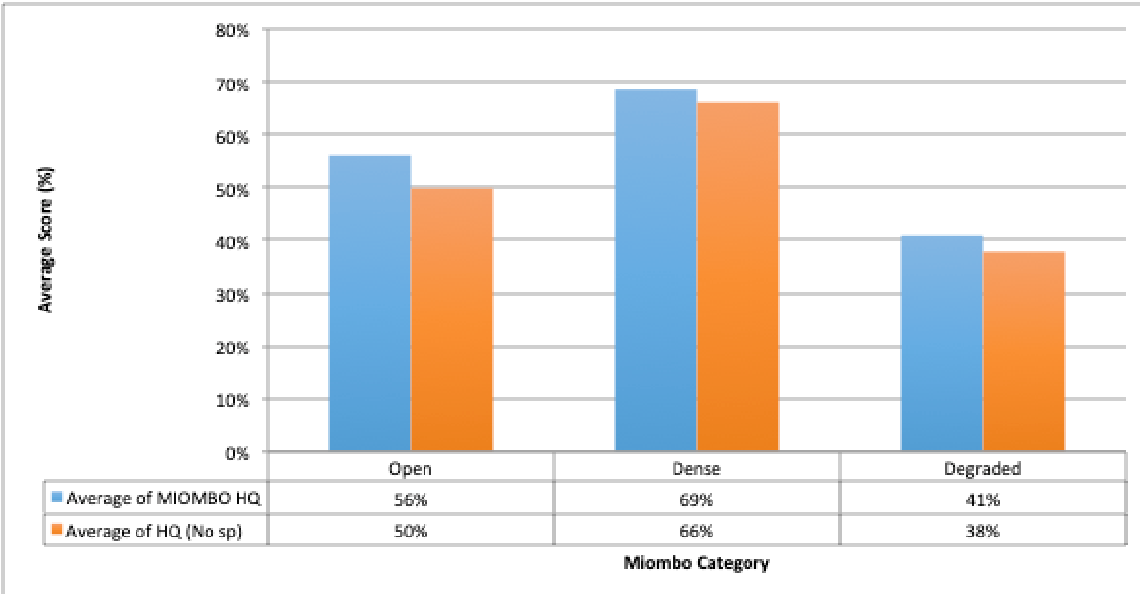



**Figure 11. Sensitivity of MIOMBO metric percentage of indicator species removal.**

## 5. Final considerations

This report presents the first step in defining a framework to assess the ecological condition of Miombo Woodlands in Mozambique, which will support decision-making in the context of the biodiversity offsetting system. The process to define this framework was based on extensive literature review, experts' consultation, field data collection and statistical analysis, which provided the team with sufficient tools to decide about the method.

The team recognizes that the metric must evolve as methods of data collection and analysis improve in the country and other elements are included. However, our results suggest that the most appropriate metric for measuring Miombo condition in Mozambique at the present time is the MIOMBO metric, for the following reasons:

- Structure and composition indicators (height, basal area, tree density and % of indicator species) can robustly be assessed in the field and compared with benchmarks.
- Relatively good technical capacity in the country to measure and analyze those indicators.
- The evidence of human activities is a complement to structure and composition indicator and adds value to the final score, as this is the key threat to miombo ecosystems in the country.
- The metric allows improvement of its indicators as better benchmarks are developed in the country, but is perfectly usable as a comparative metric even in the absence of absolute benchmarks.

Additional aspects that ought to be considered in the choice of methodology should be: the ability to be used in other forest types, the ease of application, and ease of oversight and control. The proposed MIOMBO metric appears to meet the majority of these considerations. Its applicability to other forest systems should be tested in the near future. Testing it in other miombo ecosystem types, would also be highly recommended, and may lead to further refinements.

Moving forward, it will be critical to finalize the overall mechanism for determining offset size and location in Mozambique, whether this will be an approach based on multipliers, habitat-hectares, species-focused, single proxies, etc., or a combination of several or even all of these. The lack of this framework has significantly complicated the present exercise, as the way and the degree to which habitat condition is assessed ultimately depend directly on the way in which the condition index will be applied. For example, the three-point multiplier scale used in the United Kingdom requires a much simpler evaluation of condition than the percentage based habitat hectare score used in Australia. The degree to which other elements (fauna, landscape aspects, species of concern, etc.) are or are not considered in other components of the offset system has a direct relationship to the degree to which they need to be incorporated inside the habitat condition metric. Only when clarity is reached on what type of overall biodiversity offset approach will be used in Mozambique can the current report be adapted for final use.

While it is beyond the scope of the current paper to assess a complete measurement framework for a biodiversity offset scheme in Mozambique, the flexibility of the recommended MIOMBO methodology for incorporation in a variety of systems is a further advantage. Irrespective of the final system of measurement chosen, evaluating condition should be a fundamental element, and the proposed MIOMBO metric can serve that function.

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## Annex I: Long list of Miombo habitat condition indicators.

| Criteria | Indicator | Benchmark for Miombo | | Existing National methodologies | |
|---|---|---|---|---|---|
| | | Wet (Chimoio plateau, highlands of Ilê, Namarrói, Gúruè, Náuèla, Alto Molocué, Tacuane, Milange) | Dry (Lowlands north of the Save River) | NFI | FREL |
| Landscape structure | Area (ha) | | | | |
| | Dambo % | | | | |
| | Fragment area (ha), | | | | |
| | Distance to core areas | | | | |
| | Fauna corridor (km) | | | | |
| | Human Settlements | | | | |
| Ecosystem Structure | Height (m) | 15 a 22 | 8 a 12 | Y | N |
| | # of strata | 2 | 3 | Y | N |
| | Diametric distribution | Inverted J-shape | Inverted J-shape | Y | N |
| | Density (Tree/ha) | 512± 29 | 506± 020 | Y | N |
| | Basal area ($m^2$/ha) | 11,84± 0.6 | 9,61± 0.36 | Y | N |
| | Tree Biomass (Mg/ha) | 99,89±5.91 | 62,24± 2,73 | Y | Y |
| | Density of Natural regeneration (N/ha) | | | N | N |
| | Density of stumps (n/ha) | | | N | N |
| | % Canopy Cover | >60% | 30 -<60% | N | N |
| | Tree: Grass ratios | 1:0 | | N | N |
| Composition | Dominant Species (Importance Value Index) | *B. Spiciformis* | *B. Boehmii, J. globiflora* | Y | N |

| | | | | | |
|---|---|---|---|---|---|
| | Richness | 12 a 24 | 12 a 24 | Y | Y |
| | Presence of mammal/megafauna and insects | Bees, antelopes | Elephant, zebra, antelopes, termites, bees. | N | N |
| | Presence of bird species | Zego, Calau | Zego, Calau | N | N |
| Soil condition | Mushroom density | Existing families: Amanitaceae, Cantharellaceae, Russulaceae | - | N | N |
| | % bare soils | | | N | N |
| | % organic material | | | N | N |
| Disturbances | Fires | <every 5 years | Every 3-4 years | N | N |
| | Invasive species | *Vernonanthura phosphorica* | *Lantana camara, L. Leucocephala* | N | N |
| | % of area with agriculture (ha) | | | Y | Y |
| | % of area with Charcoal and firewood collection | low | high | N | N |
| Ecosystem services | # and type of ES provided | Mushroom, tubers, roots, honey, wild fruits, firewood, charcoal, medicine, water regulation, climate regulation, nutrient cycling. | | N | N |

# Annex II: Detailed description of the metrics adjusted for this study

## 1. Germany's Biotope Valuation (BV)- German Impact Mitigation Regulation- *Eingriffsregelung*

**General description**: the method consists in building lists of biotopes types (types of land use) at local level and ascribing score values to them based on indicators.

**Metric adjustment**: the adjustment made for Miombo woodlands in Mozambique, required an analysis of which parameters were more useful to describe each indicator and define scoring thresholds within an indicator (Table 1).

**Table 1. Indicators and scores to adjust the BV metric for Miombo woodladns in Mozambique.**

| | Score |
|---|---|
| **Internal features** | |
| C1. Maturity of the Miombo | |
| Stand Basal area between <1 and 2 m2/ha | 1 |
| StandBasal area between 2.1-5 m2/ha | 2 |
| Stand Basal area between 5,1 -10m2/ha | 3 |
| Stand Basal area between 10,2-15m2/ha | 4 |
| Stand Basal area between 15.1-20m2/ha | 5 |
| Stand Basal area >20m2/ha | 6 |
| C2. Unaffected state of the Miombo (% affected by anthropogenic use vs years abandonment after anthropogenic use) | |
| % affected>50% of sampling area, less than 2years old | 1 |
| % affected> 50% of sampling area, more than 2years old | 2 |
| % affected< 50% of sampling area, less than 2years old | 3 |
| % affected< 50% of sampling area, more than 2years old | 4 |
| % affected<1% of sampling area, more than 10years olds | 5 |
| No anthropogenic evidence | 6 |
| C3. diversity of the layer structure | |
| Number of saplings (5≥dbh<10)>35% of total abundance | 1 |
| Number of saplings (5≥dbh<10)>35% of total abundance and Number of Intermediate trees (10≥dbh<30) >20% of total abundance | 2 |
| Number of saplings (5≥dbh<10)>35% of total abundance and Number of Intermediate trees (10≥dbh<30) >20% of total abundance | |
| Number of saplings (5≥dbh<10)>35% of total abundance, Number of Intermediate trees (10≥dbh<30) >20% of total abundance and Number of large trees (30≥dbh<40) > 2% of total abundance | 4 |
| Number of saplings (5≥dbh<10)>35% of total abundance, Number of Intermediate trees (10≥dbh<30) >20% of total abundance and Number of large trees (30≥dbh<40) > 2% of total abundance | 5 |

| | |
|---|---|
| Number of saplings (5≥dbh<10)>35% of total abundance, Number of Intermediate trees (10≥dbh<30) >20% of total abundance, Number of large trees (30≥dbh<40) > 2% of total abundance and Number of largest trees (dbh > 40 cm) > 0.75% of total abundance | 6 |
| C4. % ofMiombo indicator species | |
| % ofMiombo indicator species ≤5% | 1 |
| % ofMiomboindicator species ≤10% | 2 |
| % ofMiomboindicator species ≤12% | 3 |
| % of indicator species ≤15% | 4 |
| % of indicator species ≤22% | 5 |
| % of indicator species >22% | 6 |
| **External features of Miombo** | |
| C5. rarity of Miombo | Not relevant to habitat quality which is the focus of the current report |
| C6. rarity of species | |
| C7. sensitivity of Miombo | |
| C8. threat to the extent and quality of Miombo | |

Although the original metric includes a few external features of the ecosystem referred in table 1 we have not considered those for Miombo in Mozambique being the reasons two-fold:

1. Indicators C5-C7 not really applicable to the current study which is focused on habitat quality.
2. Indicator C8 is somehow covered in indicator C2.
3. These indicators rely on experts' judgment and given limited expertise in the country it is risky to include them in the metric.

The original method defines the following formula to aggregate the indicators and give the final score:

Aggregation formula: {[(C1 + C2 + C3 + C4) x (C5 + C6 + C7 + C8)]/576*100}

Based on this formula, the ecosystem may have a final score of 26 (maximum ecological condition) or 2.78 (minimum ecological condition).

According to our recommendation the formula for final score calculation of quality would be simply a sum of C1-C4, meaning the maximum score is 24 and a minimum score 4.

## 2. Metric for Biodiversity Offsetting Pilots in England (DEFRA, 2012)

**General Description**: Based upon condition and area, in order to determine a set of multipliers on the basis of 3 criteria: **Distinctiveness**, **Condition, and Area of habitat in hectares**.

**Metric adjustment**: for this exercise we used only the condition part of the metric and used the indicators referred in table 2.

**Table 2. Indicators and scores to adjust the BOE metric for Miombo woodladns in Mozambique.**

| | Indicator | Score | |
|---|---|---|---|
| # | | YES | NO |
| 1 | Abundance of indicator species (*Julbernardia globiflora* and *Brachystegia spp*.) >15% | 1 | 0 |
| 2 | A diverse age and height structure of native vegetation (Inverted J-shape diametric curve) | 1 | 0 |
| 3 | Recruitment of Miombo spp. (Saplings with 5<= DBH<10) greater than 150/ha | 1 | 0 |
| 4 | Standing trees over 40 cm dbh correspond to more than 0.75 total abundance | 1 | 0 |
| 5 | Less than 3% of land cover by agricultural and other anthropogenic operations | 1 | 0 |

The metric simply sums indicators 1-5 and categorizes the ecosystem according to its condition, as follows (Table 3):

**Table 3. Categories of ecosystem condition when using the BOE metric**

| Sum of scores | Category | Description |
|---|---|---|
| 5 | A | Good ecological condition |
| 3-4 | B | Median ecological condition |
| <=2 | C | Bad ecological condition |

Note the original metric actually scores anything less 4 as category C, but we have made that slightly less restrictive here.

## 3. Forest Integrity Assessment Tool (FIAT; Proforest, HCV Resource Network and WWF)

**General description**: Uses field forms to assess forest condition in 2 different groups: *structure and composition*, *Impacts and Threats*. In addition it used two additional conditions: key habitats and key species.

**Metric adjustment:** to test the feasibility of the metric to the national conditions, we made the adjustments presented in table 6. This adaptation may be difficult in normal circumstances, as much of the quantitative data is not normally collected when using this tool.

| **Indicator** | **Score (X)** | |
|---|---|---|
| | **YES** | **NO** |
| **STRUCTURE AND COMPOSITION** | | |
| C1: Presence of naturally fallen large trees (DBH≥39cm) | | |
| C2:> 4% of very large trees (DBH≥30cm) | | |
| C3:>32% of medium size trees (10cm<DBH<29,9 cm) | | |
| C4:>47% of saplings (5cm<DAP<9,9cm) | | |
| C5: % of grass cover | | |
| C6: =>50% of woody biomass benchmark (62.24 Mg/ha) | | |
| C7: >50% of medium/large trees with height>8m | | |
| C8: 30-60% of canopy cover | | |
| C9: >22% of relative density of Miombo indicator species | | |
| **IMPACTS AND RISKS** | | |
| I1: Presence of invasive/exotic species | | |
| I2: Presence of large trees of commercial species | | |
| I3: Evidences of illegal hunting | | |
| I4: Evidence of logging, agricultural use, pasture, | | |
| I5: Evidence of solid waste | | |
| I6: Distance to access roads or rivers <2km | | |
| I7: Presence of t species with conservation value | | |
| I8: Evidence of critical habitats | | |
| I9: Occurrence of annual fire | | |
| **CRITICAL HABITATS** | | |
| KH1: Presence of dambos | | |
| KH2: Presence of riverine forests | | |
| KH3: presence of lagoon or other wetlands | | |
| KH4: Presence of steep slopes covered with forest | | |
| **CRITICAL SPECIES** | | |
| Presence of >3% of species of concern (according to the red data list) | | |

For each indicator the response can be either Yes (X) or No (X) and the aggregation logic is calculate the % of yes (relative to the total number of responses) for structure and composition, critical habitats and critical species. For Impacts and risk indictors the interpretation is the reverse, the % of No responses is calculated, as we want to assess if the ecosystem is at risk. The final aggregation is simply the mean of the 4 indicator categories.

## 4. Madagascar Ambatovy mine project

**General description:** The metric used in the Madagascar Ambatovy mine project is divided into **habitat** and **species** metrics. The habitat condition index is measured by: the number of trees per hectare, the number of species of tree per hectare, the basal area, and the average height of the tree canopy cover, each weighted equally to come up with an overall quality score and the species metric uses the species of concern.

**Metric adjustment:** for this assignment we used only the habitat condition index part and adjusted to the Miombo as indicated in Table 4.

**Table 4. Indicators and scores to adjust the Ambatovy metric for Miombo woodladns in Mozambique.**

| Indicators | Benchmark | Score (%) |
|---|---|---|
| Abundance of trees with dbh => 5cm (N/ha) | 400-500 | Field parameter/ benchmark |
| Tree height (m) | 8-12 | Field parameter/ benchmark |
| %Miombo indicator species | 22 | N/ha of indicator species/total N/ha |
| Total basal area (m2/ha) | 8-10 | Field parameter/benchmark |

For each cluster the value found in the field is compared with benchmarks defined for Miombo giving the Score in %. However, given the variability of Miombo condition, in cases the field parameter is higher than the benchmark, we suggest using the maximum value found in the dataset to calculate the score.

## 5. MIOMBO Biodiversity Metric (adapted from the Madagascar Ambatovy mine project)

Miombo biodiversity metric is designed to address the ecological condition of the Miombo Woodlands in Mozambique. It considers that the woody component is dominant and comprises 95% of the ecosystem's biomass and thus it represents habitat condition robustly. Additionally, the woody component indicators selected for this metric (Table 1) can be objectively assessed in the field with existing national standard methods and are easily compared with current benchmarks for Miombo. The calculations are also straightforward with existing standard formulas thus reducing the likelihood of error and redundancy in the information provided. Additionally, it recognizes that there are many other important elements in Miombo ecological condition, especially when addressing its biodiversity and condition. However, these elements are either scarce in Miombo or the ability to measure them in the field is difficult in the national context (limited technical capacity and information). Thus, not all elements are considered in the MIOMBO metric but evidence of human activities is considered in this metric.

**Table 1. Woody indicators and scores for woody stock in Miombo woodlands.**

| Indicators | Benchmark | Score (%) |
|---|---|---|
| HQ1: Abundance of trees with dbh => 5cm (N/ha) | 400-500 | Field parameter/ benchmark |
| HQ2: Tree height (m) | 8-12 | Field parameter/ benchmark |
| HQ3: %Miombo indicator species | 22 | N/ha of indicator species/total N/ha |
| HQ4: Total basal area (m2/ha) | 8-10 | Field parameter/benchmark |

The MIOMBO metric combines the 5 sets of indicators in a 3 stepwise approach (Figure 1):

- In the first step habitat condition is measured by aggregating 4 indicators of wood structure and composition presented in Table 1. These indicators result from field measurements of dbh and height in trees identified at the species level. For each sampled cluster the actual indicator is compared with benchmarks for Miombo giving the Score in %. However, given the variability of Miombo condition, in cases the field parameter is higher than the benchmark (e.g. tree density), we suggest using the maximum value found in the dataset to calculate the score. The final score of wood structure and composition (HQ1-HQ4) is given by averaging the four individual %scores. This can be considered as the main reflection of the habitat condition in the study area.
- In the next step one secondary element, human activity is further considered though field observations (Table 2). Given the nature of this indicator and to reduce subjectivity, it should be observed in the landscape context and in consultation with local people, not only at the cluster/plot level.

**Table 2. Indicator of human activity (HQ5)**

| Indicator | Score | Assessment method |
|---|---|---|
| No anthropogenic use evident | 1 | Field observation in the landscape context of logging, charcoal, agriculture, etc. |
| Anthropogenic use on less 75% of area | 2 | |
| Anthropogenic use on less 50% of area | 3 | |
| Anthropogenic use on less 25% of area | 4 | |

- In the third and final step the HQ1-HQ4 is combined with HQ5 averaging the individual scores.

The final decision about the habitat condition is made using the reference thresholds in Table 3.

**Table 3. Categories of ecosystem condition when using the MIOMBO biodiversity metric.**

| Habitat Condition | Description | Average score (%) |
|---|---|---|
| Good | Woody component is in good condition as compared to the benchmarks and more than one secondary element are present. | 60-100 |
| Average | Woody component is in fairly good condition and 1-2 secondary elements are present | 30-59 |
| Bad | Woody component is in bad condition and none of the secondary elements are present | <30 |

# Annex III: Summary of the discussions during the technical meeting

REF: WCS/Biofund 22/04/2019
Série:Miombo/01. 22/04/2019

**Sumário de notas da reunião técnica sobre o desenvolvimento de métricas para avaliação da condição ecológica de Miombo**

Data: 22/04/2019

No dia 22 de Abril de 2019, realizou-se um workshop de especialistas, referente à primeira fase do projecto de desenvolvimento de métricas para avaliação da condição ecológica de Miombo, no âmbito do desenvolvimento do sistema de contrabalanços de biodiversidade em Moçambique. O evento foi co-organizado pelo WCS, o Biofund e o CEAGRE no Complexo Pedagógico da Universidade Eduardo Mondlane, e contou com a presença de 12 participantes (lista de presenças em anexo), dentre eles especialistas de flora e fauna, Consultores de Avaliação do Impacto Ambiental, representantes do governo (MITADER), e da União Internacional para a Conservacão da Natureza (IUCN). O workshop tinha como objectivos apresentar o progresso do processo de desenvolvimento da ferramenta de avaliação da condicão do Miombo, bem como, discutir com especialistas nacionais os indicadores de Miombo utilizados, assim como a praticabilidade das ferramentas existentes em outros países, com vista a garantir a definição de uma ferramenta útil e adequada ao contexto nacional.

O Director do Projecto COMBO em Moçambique, Hugo Costa, deu uma visão geral do projecto e seus objectivos. Em seguida a Prof. Natasha Ribeiro, coordenadora da equipe de consultores do projecto e Moderadora do Workshop, apresentou a abordagem metodológica, usada para o desenvolvimento da ferramenta desde a definição dos indicadores até ao ajuste e testagem das diferentes ferramentas eixstentes em outros países. De realçar que, o workshop teve duas secções, a primeira consistiu na apresentação dos indicadores usados para definição dos benchmarks, seguida de debate e selecção de indicadores adequados para o contexto de Miombo, e a segunda na apresentação e testagem de diferentes metodologias e seguida de debate sobre a praticabilidade das ferramentas em análise.

**Notas/sugestões**

Após a apresentação e discussão na primeira secção, foram deixadas várias sugestões em relação aos indicadores e as metodologias para avaliação da condicão do Miombo**.**

**Indicadores**

- A rebrotação por cepos, pode ser ignorado, pois, já está captado na regeneração natural.

- Usar a densidade de espécies indicadoras em detrimento do Índice de Valor de Importância (IVI), devido à complexidade de procedimentos para o càlculo do IVI.

- O uso de 15% para a abundância das espécies indicadoras de Miombo é optimo, porém, deve ser averiguado com as análises dos dados do IFN, pois, provavelmente esteja muito abaixo da média.

- Deve-se repensar a altura (8-12 m), e a classe diamétrica de large trees (DAP≥40 cm), visto que, esses atributos dependem do tipo de Miombo/condições edafoclimáticas de cada região, podendo excluir o Miombo com elementos costeiros.

- Deve pensar-se em incluir espécies com valor comercial, com moratário de exploração.

- A presença de fauna e matéria orgânica (solo e serrapilheira) pode ser retirado dos indicadores, pois, para o propósito de contrabalanço, seria melhor trabalhar com a estrutura e composição floristica, ignorando a dimensão funcional, uma vez que já está representado na estrutura e composição.

- Substituir frequência de queimadas por densidade de espécies indicadoras de queimadas (e.g. *Diplorhynchus condylocarpon* e Combretaceae), porque o cálculo de frequências de queimadas é bastante complexo e requere conhecimneto de remote sensing e GIS.

- A presença de cogumelos pode ser retirado dos indicadores, uma vez que, são muito voláteis, ou seja, a sua presença depende da época do ano (época chuvosa**).**

**Metodologias**

- Ajustar os critérios de pontuação na metodologia da Alemanha BV, possivelmente não usar esta metodologia que se mostra complexa.
- Rever os critérios de pontuação na metodologia da Austrália (VQM), sobretudo o critério de sanidade, pois, a sua avaliação é bastante subjectiva e complexa.
- Deve recorrer-se ao estudo de mapeamento de habitats de 2016, para definição de habitats críticos.
- Deve pensar-se melhor a inclusão ou não, termiteiras como habitats chaves.
- Incluir os *swamp forest* como habitats chaves nos critérios de pontuação da metodologia de FITA.
- Nas espécies com valor de conservação pode se incluir espécies endémicas e as comerciais que estão na lista de moratória de exploração na metodologia de FITA.
- As metodologias de BOE e TIFA, foram consideradas como as mais pragmáticas e devem ser ajustadas ao contexto nacional, mas sem perder a consistência.

**Decisões/recomendações**

- Sérgio, deve solicitar a base de dados brutos do Inventário Florestal Nacional, agregar com os dados de RNN e RNP, para melhor tirar conclusões sobre os benchmarks.
- Levantamento de dados de campo, Pomene, não seria melhor sítio para validar as metodologias, pois, o Miombo de Pomene não representa o Miombo Nacional. Foi recomendado fazer o trabalho no PN Zinave.

Face às sugestões dadas pelos especialistas em relação à praticabilidade das ferramentas/metodologias em análise, nos próximos passos prossiguiremos com as quantro ferramentas ou apenas com as duas consideradas pragmáticas (BOE e TIFA)?

# Annex IV. User's guide

**Manual para a avaliação ecológica da condição ecológica das florestas de Miombo no âmbito dos contrabalanços da biodiversidade em Moçambique.**

**DEFINIÇÕES**

**MÉTRICA DE BIODIVERSIDADE**: uma estrutura projectada para avaliar quantitativamente a condição ecológica de um ecossistema.

**CLUSTER**: unidade de amostragem de 1ha (100 x 100 m), que é um conglomerado de quatro parcelas (20 x 50 m) localizadas nos quatro cantos do cluster quadrado.

**MIOMBO DENSO**: parte da categoria florestal moçambicana de Florestas Semi-decíduas com cobertura de cobertura acima de 50%. Geralmente correspondem a um estado não perturbado de Miombo.

**MIOMBO DEGRADADO**: a área florestal que foi convertida para um uso de terra diferente (a cobertura de copas inferior a 30%) ou um ou mais de seus serviços ecossistémicos está comprometido.

**CONDIÇÃO ECOLÓGICA**: estado dos ecossistemas, que incluem suas características físicas, químicas e biológicas e os processos e interacções que os conectam. Neste estudo, a condição ecológica é medida como o estado das características biológicas como expressão de outras características no sistema.

**FLORESTA**: Uma porção de terra com árvores com potencial para atingir uma altura de 3m na maturidade, uma cobertura de copa igual ou superior a 30% e que ocupa pelo menos 1 ha (DINAF, 2018).

**MIOMBO ABERTO**: parte da categoria florestal moçambicana de florestas semidecíduas (DINAF, 2018) com uma cobertura de dossel entre 30-50%. O Miombo aberto pode ser um estado maduro ecológico em áreas secas e costeiras ou um estado de transição entre o Miombo degradado e o intacto.

**MIOMBO NÃO PERTURBADO**: uma floresta decídua fechada e não espinhosa, dominada por três gêneros de árvores: *Brachysregia*, *Julbernardia* e *Isoberlinia*, ocorrendo em solos geologicamente velhos e pobres em nutrientes, na zona de precipitação uni-modal (600-1400 mm em uma estação). A camada arbustiva é variável em densidade e composição. A cobertura do solo varia de um crescimento denso de gramíneas a uma cobertura esparsa de gramíneas e plantas herbáceas. Queimadas antropogénicas e herbivoria são os principais factores de distúrbio das florestas de Miombo.

# 1. Introdução

O processo de Avaliação do Impacto Ambiental (AIA) está instituído em Moçambique através do Decreto 54/2015 de 31 de Dezembro. Este instrumento obriga a que qualquer actividade de desenvolvimento sócio-económico no país seja submetida ao processo de análise e avaliação dos impactos ambientais. Neste contexto, a análise e aplicação de medidas de mitigação é uma etapa obrigatória do processo. Segundo o decreto 54/2015 medidas de mitigação são o conjunto de acções que visa minimizar ou evitar os efeitos negativos de uma actividade sobre o ambiente biofísico e sócio-económico. Portanto, a mitigação prevê um processo hierárquico de análise.

A hierarquia da mitigação é chave para o processo de Avaliação do Impacto Ambiental (AIA), uma vez que visa, através de um processo estruturado e sistematizado, lidar com os impactos ambientais resultantes de projectos de desenvolvimento e assim, reduzir a pegada ecológica do desenvolvimento humano. Neste contexto, a hierarquia da mitigação pressupõem 4 decisões hierárquicas: (i) evitar, (ii) minimizar, (iii) restaurar e (iv) contrabalançar. Estes quatro processos ou níveis de decisão devem ser analisados de forma detalhada no âmbito da AIA.

Os contrabalanços da biodiversidade enquadram-se na categoria (iv) da hierarquia da mitigação e segundo o decreto 54/2015 define-se como " o resultado mensurável da conservação resultante de acções destinadas a compensar impactos residuais (não mitigáveis) adversos significativos sobre a biodiversidade, decorrentes do desenvolvimento de um projecto, após terem sido tomadas as medidas apropriadas de prevenção e de mitigação". O conceito visa atingir Nenhuma Perda Líquida (NPL) de biodiversidade ou, quando possível, um Ganho Líquido (GL) de Biodiversidade. A sua implementação é feita geralmente fora do local do projecto, em áreas com condições sociais e ambientais viáveis.

O desenho de um sistema de contrabalanços da biodiversidade a nível nacional é assim, primordial para a prossecução do postulado no regulamento de AIA sendo umas das primeiras fases, a avaliação da condição ecológica do ecossistema. Esta permite, no âmbito do Estudo do Impacto Ambiental (EIA), determinar o nível de conservação do ecossistema o que apoiará a fase posterior de definição do valor final a contrabalançar. Neste contexto, o presente manual pretende ser um guião base de avaliação ecológica do ecossistema Florestas de Miombo no contexto de Moçambique visando padronizar o levantamento e análise de informação ecológica. Pretende-se que este documento funcione como um instrumento prático de planificação, colheita e análise de informação ecológica em estudos de impacto ambiental.

## PARTE A: Breve descrição das florestas de Miombo em Moçambique.

Em Moçambique, as florestas de Miombo ocorrem desde o Norte do Rio Save (norte da província de Inhambane) até ao Norte do país (Povincias de Niassa e Cabo-Delgado) e cobrem mais de 65% do território nacional (Marzoli, 2007). Contudo, o último inventário florestal nacional indica que a cobertura florestal nacional é de 40% do território nacional, mas não revela especificamente a contribuição do Miombo. Assim, neste manual utiliza-se como referência a distribuição referida por Wild and Barbosa (1967) a qual até à data é a mais detalhada para o país (Figura 1). Contudo, deve-se reconhecer que esta figura se encontra desactualizada.

A maioria das florestas de Miombo em Moçambique pertencem à categoria de Miombo seco, com influencia de elementos costeiros na faixa costeira e elementos de Miombo húmido sempre-verde em zonas do interior e da zona norte do país. Em geral, o Miombo seco das zonas baixas é dominado pelas seguintes espécies arbóreas: *Julbernardia globiflora, Brachystegia boehmii, Brachystegia spiciformis, Pseudolachnostylis maprouneifolia, Diplorynchus condilocarpon, Burkea africana, Uapaca kirkiana*, entre outras. Variações desta composição de espécies podem ocorrer na costa e nas zonas altas, onde as espécies de Miombo podem estar associadas a espécies típicas dessas zonas. Espécies pertencentes à família a Combretacea podem igualmente dominar em áreas de solos arenosos bem como em zonas onde distúrbios como o fogo e herbivoria são intensos (Chidumayo 1997, Ribeiro et al. 2008).

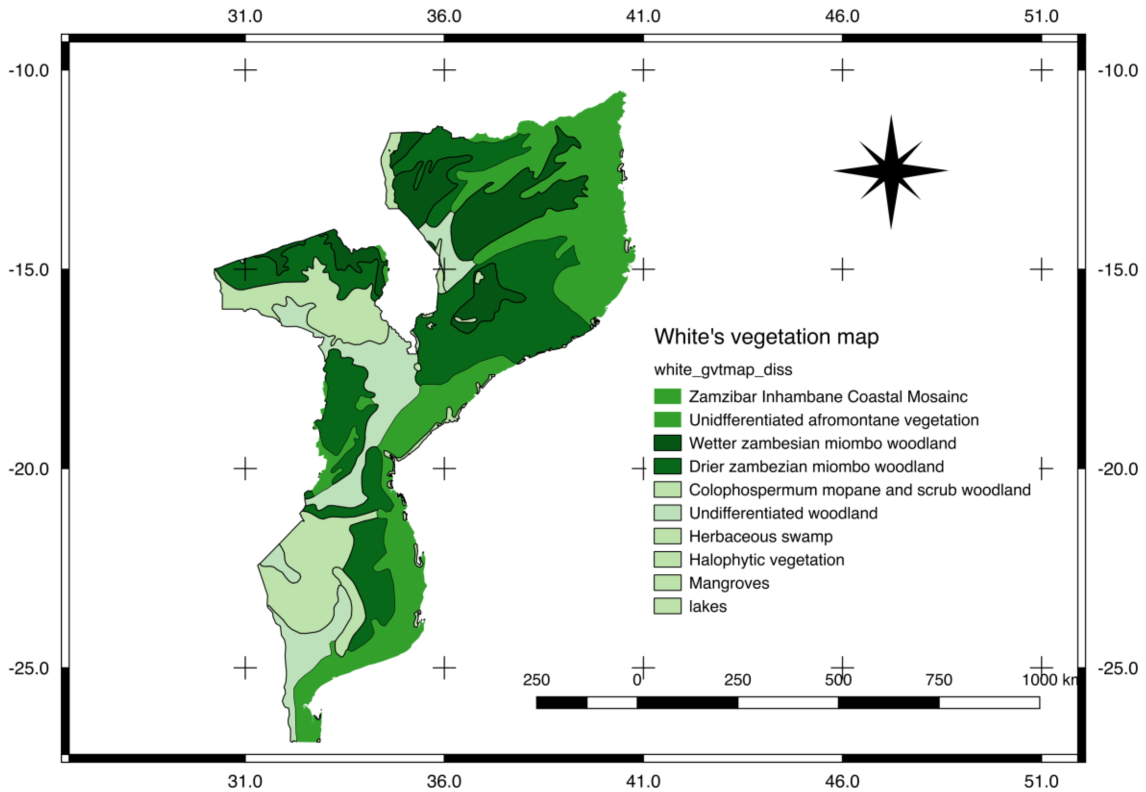



**Figura1: Distribuição de Miombo em Moçambique (Fonte: White, 1983).**

De acordo com Ribeiro et al. (2002) as principais diferenças associadas aos dois tipos de Miombo em Moçambique são:

**Miombo Húmido:** ocorre acima do 1000 m de altitude em áreas com precipitação média anual de 1,200 to 1,800 mm em topografia ondulada. As áreas de ocorrência incluem: planalto de Chimoio, na província de Manica, zonas altas da Provincia da Zambézia tais como: Ile, Namarrói e os planaltos adjacentes de Gúruè, Náuèla, Alto Molocué, Tacuane e Milange. É dominado pela espécie *Brachystegia spiciformis*, associada a *Pteleopsis*, *Erythrophleum* e *Newtonia*. A altura das árvores encontra-se entre 15 a 22 m, sendo a cobertura de copa fechada (>60% de cobertura de copa) e a cobertura de gramíneas bastante reduzida.

**Miombo Semi-decíduo**: ocorre acima de 500 m de altitude em áreas com precipitação média anual de 900 to 1,400 mm tais como: a zona central central (Norte e Sul do Rio Zambeze). É dominand pelas espécies: *Brachystegia spiciformis*, *Julbernardia globiflora*, *B. boehmii*, *Pterocarpus angolensis*, *Piliostigma thonningii*, *Swartzia madagascariensis*, *Dombeya spp., Burkea africana, Vitex payos, Cussonia spicata, Millettia stuhlmanii*, etc.Com árvores entre os 8-15m de altura, uma cobertura de copa média (40-60%) e uma densidade de gramíneas rala.

**Miombo Seco:** ocorre em áreas de baixa altitude entre os 50-800 m, com precipitação média anual de 600 to 800 (1000) mm. É considerado o tipo de Miombo mais dominante do país distribuindo-se pelas terras baixas de Manica, Sofala, Tete, Zambezia e Niassa, enortedeInhambane e Gaza (com precipitacao entre 400-800 mm). As espécies dominantes deste tipo de Miombo são: *Brachystegia boehmii*, *Julbernardia globiflora*, *Burkea africana*, *Pseudolachnostylis maprouneifolia*, *Crossopterix febrifuga*, *Diplorhynchus condylocarpon*, etc. com árvores entre os 8 e os 10 m de altura, uma cobertura de copa rala (20-40%) e uma cobertura de gramíneas muito densa.

Este manual refere-se especificamente ao tipo de Miombo mais abundante no país, Miombo seco, para o qual foram definidos os parâmetros ecológicos de referência indicados na tabela 1, com base na literatura e no inventários florestal nacional.

**Tabela 1: Parâmetros ecológicos de referência para as florestas de Miombo em Moçambique.**

| **Parâmetro ecológico** | **Referência para Mocambique** |
|---|---|
| Cobertura de copa (%) | 30-60 |
| Altura (m) | 8-12 |
| Área Basal ($m^2$/ha) | 8-10 |
| Densidade de árvores (dap≥5 cm; N/ha) | 400-500 |
| Recrutamento (plântulas com 5≤dap<10) (N/ha) | 150 |
| Biomassa arbóreas (Mg/ha) | 62.2 |
| % de cobertura de gramíneas | 100 (composição de espécies: *Hyparrhenia*, *Andropogon*, *Loudetia*, *Digitaria*e*Eragrostis*e regeneração de espécies arbóreas) |
| Espécies indicadores de Miombo (*Brachystegia spp e Julbernardia globiflora)* | 22% do total de espécies |

| | |
|---|---|
| Espécies indicadoras de fogo | *Dyplorhynchus condilocarpon*, especies da família Combretaceae |

## PARTE B: Etapas para o uso do método de avaliação da condição ecológica

**Etapa 1: Definição do desenho de mostragem**

Esta etapa refere-se aos aspectos de amostragem de campo para o levantamento de informação ecológica representativa do local estudado. Para efeitos de harmonização com as metodologias nacionais, esta fase considera a metodologia padrão do inventário florestal nacional e portanto, a consulta do manual do IFN deve ser efectuada paralelamente a este guião. Aqui, apresenta-se um resumo do desenho de amostragem, o qual deve seguir os seguintes passos:

**PASSO 1: estratificação da área de estudo**

A área a ser levantada pode ser constituída por vários tipos florestais e/ou vários tipos de Miombo (denso, aberto). Neste contexto, é importante que seja efectuada uma análise inicial dos tipos existentes na área de estudo com vista a: (i) discriminar as florestas de Miombo dos outros tipos florestais/de vegetação (deve ser usada a escala de classificação do IFN); e (ii) discriminar diferentes densidades de Miombo. A última pode resultar de variações naturais na condição ecológica de Miombo ou de influências antropogénicas e, esta diferenciação deverá ser detectada durante a amostragem de campo. Para esta etapa, a equipa deverá recorrer às ferramentas de análise espacial de imagens de satélite as quais estão gratuitamente disponíveis na internet (e.g. www.glovis.usgs.gov; www.earth.esa.int, entre outros). A estratificação pode igualmente ser efectuada usando as imagens disponíveis em Google Earth, digitalizando polígonos referentes aos diferentes tipos de vegetação e/ou densidades de Miombo. Portanto, para esta etapa é crucial que a equipa de EIA integre um especialista em teledetecção e GIS.

**PASSO 2: determinação da intensidade de amostragem**

A intensidade (esforço) de amostragem é a razão entre o número de unidades amostrais e o número total de unidades da população (floresta de Miombo). A intensidade de amostragem pode ser determinada através de dois procedimentos principais: em função da variabilidade da população, do erro de amostragem admitido e da probabilidade de confiança fixada; ou em função do tempo e recursos disponíveis para a realização do inventário (Brena *et al*., 2001). Para o primeiro caso, a intensidade de amostragem deve ser determinada usando a fórmula 1 e considerando-se o erro de amostragem <= 10% ao nível significância de 5%.

$$n = \frac{t^2 * \left(\sum_{h=1}^{L} Ph * Sh\right)^2}{E^2} \qquad \text{(equação 1)}$$

Onde: n é o número total de unidades amostrais na população, t é o *t de Student* para um número infinito de graus de liberdade, Phéa proporção da área do estrato h (Ah) em relação à área total (A), L é o número total de estratos na população, Sh é o desvio padrão do estracto h e E é o erro admissível para o valor médio. O desvio padrão de cada tipo florestal deve ser obtido através de uma análise preliminar da área.

A intensidade de amostragem pode igualmente ser fixada em função do tempo disponível para a realização do estudo de campo, ou pelos recursos financeiros, humanos e materiais existentes. Nestas condições, a intensidade de amostragem é decorrente da quantidade de trabalho que pode ser realizado em determinado tempo, ou com os recursos colocados à disposição. Com isso não é possível fixar o erro de amostragem requerido para as estimativas do inventário. O erro resultante será maior ou menor, dependendo das características da floresta (Péllico & Brena, 1997).

**PASSO 3: alocação das unidades amostrais**

em cada estracto de vegetação, serão alocadas unidades de amostragem de forma aleatória. Por forma a uniformizar com as metodologias padrão a nível nacional nomeadamente o Inventário Florestal nacional, deve ser usado o “Cluster” como unidade de amostragem (Figura 1). Cada “cluster” cobre 1 ha e é composto por 4 parcelas de 0.1 ha (20 m x 30 m) de área, localizadas a 50 metros uma das outras. Dentro das parcelas de amostragem devem ser estabelecidas sub-parcelas de 10 m x 25 m para avaliação da regeneração natural.

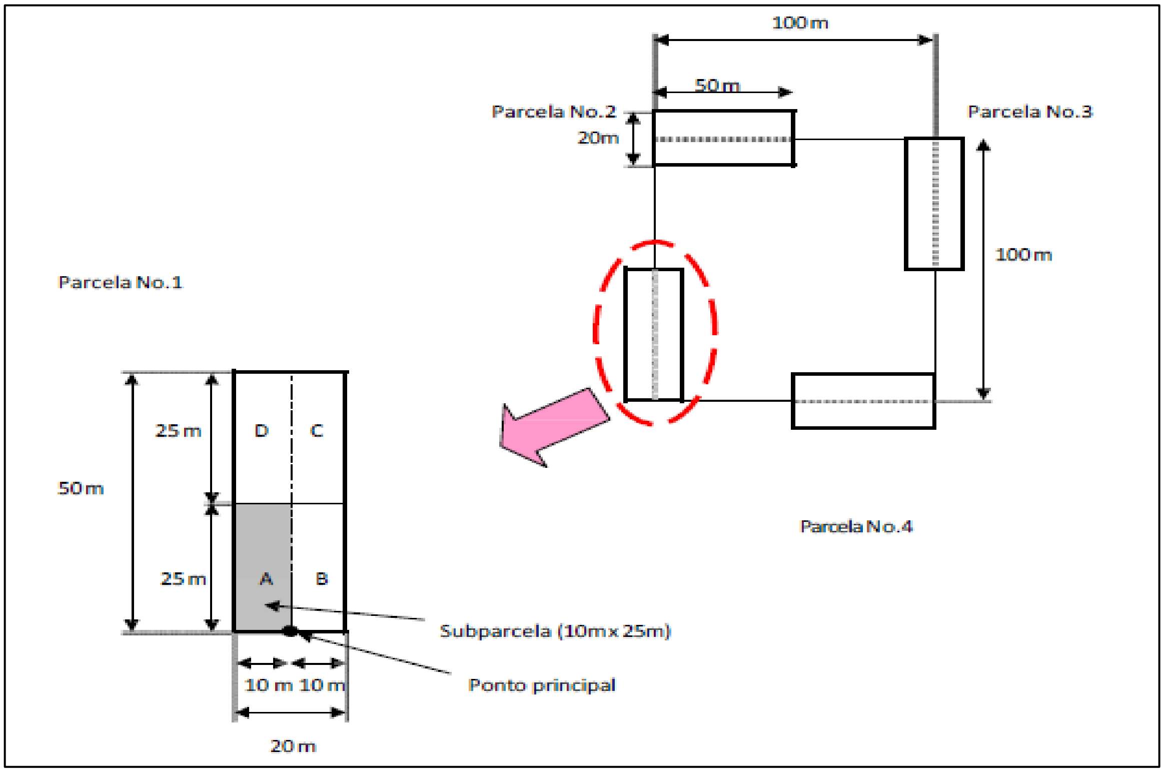



**Figura 2: Representação esquemática do cluster, parcela e subparcela de amostragem (Fonte: DINAF, 2016).**

## ETAPA 2: levantamento dos dados de campo

### PASSO 1: Levantamento de parâmetros dendrométricos

Para efeitos deste manual, os parâmetros dendrométricos a serem levantados nas parcelas de amostragem (Anexo 1) para todos os indivíduos arbóreos e arbustivos com diâmetro à altura do peito (DAP) => 5cm são:

- Identificação da espécie, recorrendo a várias ferramentas, as quais devem ser usadas conjuntamente para aumentar a precisão da identificação, nomeadamente: guias de campo, especialistas em botânica, conhecimento local e colheita de espécimenes para identificação em herbário.
- Diâmetro à altura do peito (DAP, cm), recorrendo aos instrumentos apropriados como a Suta e/ou fita diamétrica.
- Altura (m), usando um instrumento medidor de altura (hipsómetro) ou estimativa visual para o caso de árvores com menos de 5m.

**PASSO 2: Levantamento de evidências de actividade humana**

Dado que o objectivo da avaliação é avaliar a condição ecológica de Miombo, a observação da evidência de actividade humana é importante, principalmente porque nas condições actuais do país, poucas áreas estão isentas de acção humana. A avaliação deste factor visa complementar as variáveis quantitativas levantadas no passo 1 para providenciar uma avaliação completa da área, a qual pode não ser reflectida na metodologia de avaliação da condição ecológica.

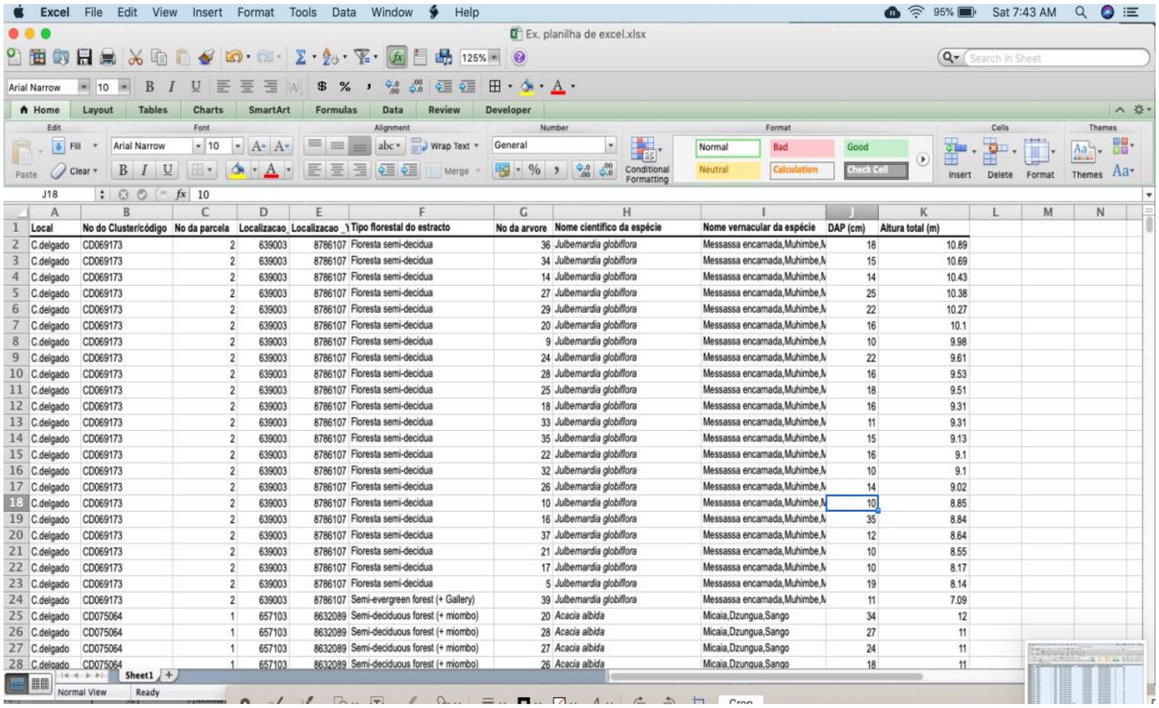
Esta variável deve ser avaliada usando os seguintes critérios:

| **Indicador** | **Score** |
|---|---|
| Sem evidencia de actividades antropogénicas | 1 |
| Actividade antropogénica em 75% da área | 2 |
| Actividade antropogénica em 50% da área | 3 |
| Actividade antropogénica em 25% da área | 4 |

## ETAPA 3: Análise dos dados de campo

**PASSO 1: Organização dos dados**

Após a colheita dos dados de campo, estes devem ser organizados em planilhas de Excel para posterior análise. Os dados devem ser organizados para reter a informação referente a cada parcelas medida no campo, devendo ser estruturadas como se indica na Figura 2. A unidade de análise deve ser o cluster, pelo que no caso da amostragem de campo proposta, a área de amostragem para o *cluster* é de 0.4 ha (4 parcelas de 0.1ha).



| Local | No do Cluster/código | No da parcela | Localizacao_ | Localizacao_\ | Tipo florestal do estracto | No da arvore | Nome cientifico da espécie | Nome vernacular da espécie | DAP (cm) | Altura total (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 36 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 18 | 10.89 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 34 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 15 | 10.69 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 14 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 14 | 10.43 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 27 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 25 | 10.38 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 29 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 22 | 10.27 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 20 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 16 | 10.1 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 9 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 10 | 9.98 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 24 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 22 | 9.61 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 28 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 16 | 9.53 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 25 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 18 | 9.51 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 18 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 16 | 9.31 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 33 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 11 | 9.31 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 35 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 15 | 9.13 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 22 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 16 | 9.1 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 32 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 10 | 9.1 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 26 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 14 | 9.02 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 10 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 10 | 8.85 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 16 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 35 | 8.84 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 37 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 12 | 8.64 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 21 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 10 | 8.55 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 17 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 10 | 8.17 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Floresta semi-decidua | 5 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 19 | 8.14 |
| C.delgado | CD069173 | 2 | 639003 | 8786107 | Semi-evergreen forest (+ Gallery) | 39 | *Julbernardia globiflora* | Messassa encarnada,Muhimbe,N | 11 | 7.09 |
| C.delgado | CD075064 | 1 | 657103 | 8632089 | Semi-deciduous forest (+ miombo) | 20 | *Acacia albida* | Micaia,Dzungua,Sango | 34 | 12 |
| C.delgado | CD075064 | 1 | 657103 | 8632089 | Semi-deciduous forest (+ miombo) | 28 | *Acacia albida* | Micaia,Dzungua,Sango | 27 | 11 |
| C.delgado | CD075064 | 1 | 657103 | 8632089 | Semi-deciduous forest (+ miombo) | 27 | *Acacia albida* | Micaia,Dzungua,Sango | 24 | 11 |
| C.delgado | CD075064 | 1 | 657103 | 8632089 | Semi-deciduous forest (+ miombo) | 26 | *Acacia albida* | Micaia,Dzungua,Sango | 18 | 11 |

**Figura 3: exemplo da organização dos dados de campo na planilha em Excel.**

**PASSO 2: Análise dendrométrica**

Para efeitos deste manual a análise de dados, ao nível do *cluster*, deve centrar-se nos seguintes parâmetros estruturais:

1. **Densidade de árvores (N/ha)** com dap => 5cm, calculada usando a equação 2

$$Densidade\ de\ árvores\ \left(\frac{N}{ha}\right) = \frac{Número\ total\ de\ árvores}{0.4} \qquad \text{(Equação 2)}$$

Onde: N= número total de árvores, ha= unidade de área

2. **Área basal (m2/ha)** estimada para cada espécie dentro do estracto usando a equação 3.

$$G = \sum_{ni}^{Ni} gi \qquad \text{(Equação 3)}$$

onde: G é a área basal total do cluster, ni= número de indivíduos da espécie i; N=total de indivíduos da espécie no cluster; gi= área basal individual da espécie i. A área basal do *cluster* será o somatório das áreas basais individuais por espécie.

3. **Altura média (m**), medida como o parâmetro estatístico médio para todas as árvores presentes no *cluster*.

4. **Densidade de espécies indicadoras de Miombo (%N/ha),** medida como a participação percentual das espécies *Julbernardia globiflora* e *Brachystegia sp.* Relativamente ao total de densidade de árvores no *cluster*, como apresenta a equação 4.

$$\%\ espécies\ indicadoras = \frac{\sum Densidade\ de\ J.globiflora\ \ e\ Brachystegia\ sp.(\frac{N}{ha})}{densidade\ total\ de\ árvores\ (\frac{N}{ha})} \qquad \text{(Equação 4)}$$

**ETAPA 4: aplicação da métrica MIOMBO para a avaliação da condição ecológica**

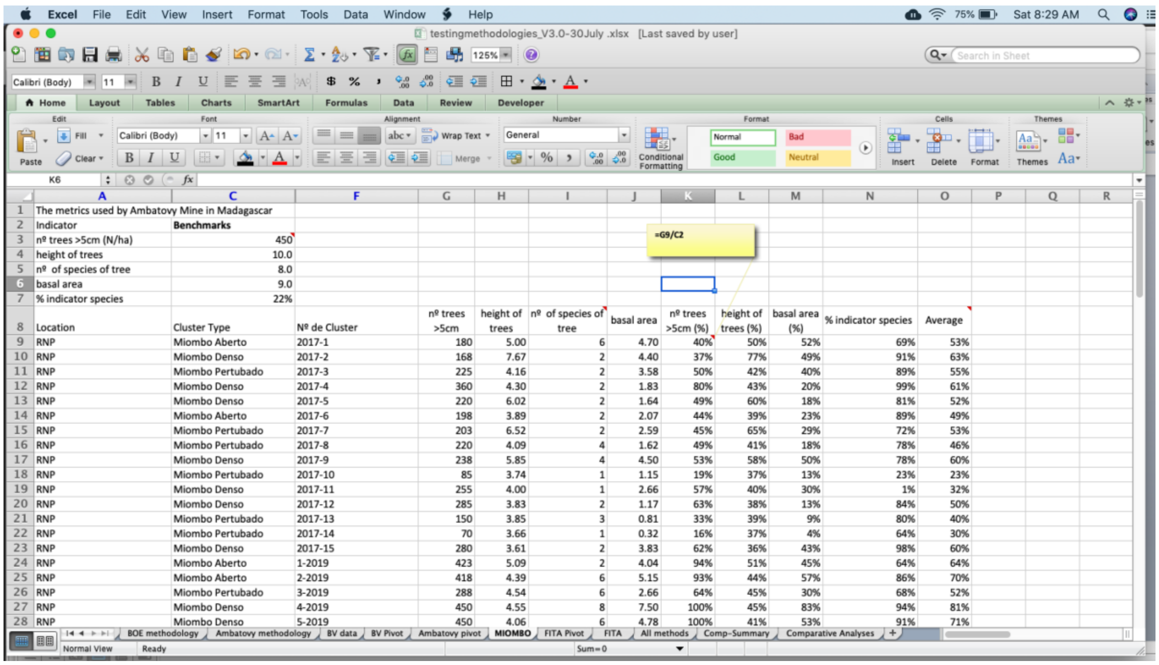
**PASSO 1: Consideração dos parâmetros de referência para as florestas de Miombo**

Como referido anteriormente, a consideração dos parâmetros de referência é extremamente importante para a definição da condição ecológica de qualquer ecossistema e, as florestas de Miombo em Moçambique possuem esses parâmetros. Este permitem uma comparação com a realidade de terreno para reduzir a subjectividade na tomada de decisão sobre a condição ecológica. Para a métrica MIOMBO foram considerados os seguintes parâmetros de referência:

- Densidade de árvores acima de 5 cm de dap (N/ha): 400-500 árvores/ha.
- Altura total: 8-12 m
- Área basal: 8-10 $m^2$/ha
- Participação relativa de espécies indicadoras de Miombo (*Julbernardia globiflora* e *Brachystegia spp)*: 22% do total da densidade de indivíduos na área de amostragem.

## PASSO 2: Cálculo participação relativa de cada indicador

Nesta fase pretende-se comparar os valores obtidos no campo com as referências estabelecidas no passo 1. Para tal, a base de cálculo refere-se à contribuição relativa do parâmetro em relação à referência tal como exemplificado na figura 3.



| | | |
|---|---|---|
| The metrics used by Ambatovy Mine in Madagascar | | |
| Indicator | **Benchmarks** | |
| nº trees >5cm (N/ha) | 450 | |
| height of trees | 10.0 | |
| nº of species of tree | 8.0 | |
| basal area | 9.0 | |
| % indicator species | 22% | |

| Location | Cluster Type | Nº de Cluster | nº trees >5cm | height of trees | nº of species of tree | basal area | nº trees >5cm (%) | height of trees (%) | basal area (%) | % indicator species | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RNP | Miombo Aberto | 2017-1 | 180 | 5.00 | 6 | 4.70 | 40% | 50% | 52% | 69% | 53% |
| RNP | Miombo Denso | 2017-2 | 168 | 7.67 | 2 | 4.40 | 37% | 77% | 49% | 91% | 63% |
| RNP | Miombo Pertubado | 2017-3 | 225 | 4.16 | 2 | 3.58 | 50% | 42% | 40% | 89% | 55% |
| RNP | Miombo Denso | 2017-4 | 360 | 4.30 | 2 | 1.83 | 80% | 43% | 20% | 99% | 61% |
| RNP | Miombo Denso | 2017-5 | 220 | 6.02 | 2 | 1.64 | 49% | 60% | 18% | 81% | 52% |
| RNP | Miombo Aberto | 2017-6 | 198 | 3.89 | 2 | 2.07 | 44% | 39% | 23% | 89% | 49% |
| RNP | Miombo Pertubado | 2017-7 | 203 | 6.52 | 2 | 2.59 | 45% | 65% | 29% | 72% | 53% |
| RNP | Miombo Pertubado | 2017-8 | 220 | 4.09 | 4 | 1.62 | 49% | 41% | 18% | 78% | 46% |
| RNP | Miombo Denso | 2017-9 | 238 | 5.85 | 4 | 4.50 | 53% | 58% | 50% | 78% | 60% |
| RNP | Miombo Pertubado | 2017-10 | 85 | 3.74 | 1 | 1.15 | 19% | 37% | 13% | 23% | 23% |
| RNP | Miombo Denso | 2017-11 | 255 | 4.00 | 1 | 2.66 | 57% | 40% | 30% | 1% | 32% |
| RNP | Miombo Denso | 2017-12 | 285 | 3.83 | 2 | 1.17 | 63% | 38% | 13% | 84% | 50% |
| RNP | Miombo Pertubado | 2017-13 | 150 | 3.85 | 3 | 0.81 | 33% | 39% | 9% | 80% | 40% |
| RNP | Miombo Pertubado | 2017-14 | 70 | 3.66 | 1 | 0.32 | 16% | 37% | 4% | 64% | 30% |
| RNP | Miombo Denso | 2017-15 | 280 | 3.61 | 2 | 3.83 | 62% | 36% | 43% | 98% | 60% |
| RNP | Miombo Aberto | 1-2019 | 423 | 5.09 | 2 | 4.04 | 94% | 51% | 45% | 64% | 64% |
| RNP | Miombo Aberto | 2-2019 | 418 | 4.39 | 6 | 5.15 | 93% | 44% | 57% | 86% | 70% |
| RNP | Miombo Pertubado | 3-2019 | 288 | 4.54 | 6 | 2.66 | 64% | 45% | 30% | 68% | 52% |
| RNP | Miombo Denso | 4-2019 | 450 | 4.55 | 8 | 7.50 | 100% | 45% | 83% | 94% | 81% |
| RNP | Miombo Denso | 5-2019 | 450 | 4.06 | 6 | 4.78 | 100% | 41% | 53% | 91% | 71% |



Figura 4: exemplo do cálculo da contribuição relativa do indicador ecológico.

Para este passo, é importante referir que devido a alta variabilidade de Miombo no país, para algumas áreas pode acontecer que os valores obtidos no campo estejam acima dos parâmetros de referência. Neste caso, a participação relativa deve ser calculada usando o maior parâmetro obtido na área de estudo. Por exemplo, se a densidade máxima de indivíduos acima de 5cm de dap na área de estudo for de 1000 árvores/ha, a participação relativa do cluster será a densidade (n/ha) do cluster relativamente a 1000 (e não 400-500 indivíduos/ha que é a referência).

## PASSO 3: cálculo da condição ecológica

Os parâmetros calculados no passo 2 correspondem à estrutura e composição de Miombo na área de influência relativamente aos valores de referência nacionais e devem ser agregados através da média aritmética dos 4 indicadores individuais e designa-se de HQ1. Este reflecte a condição ecológica da componente arbórea do ecossistema.

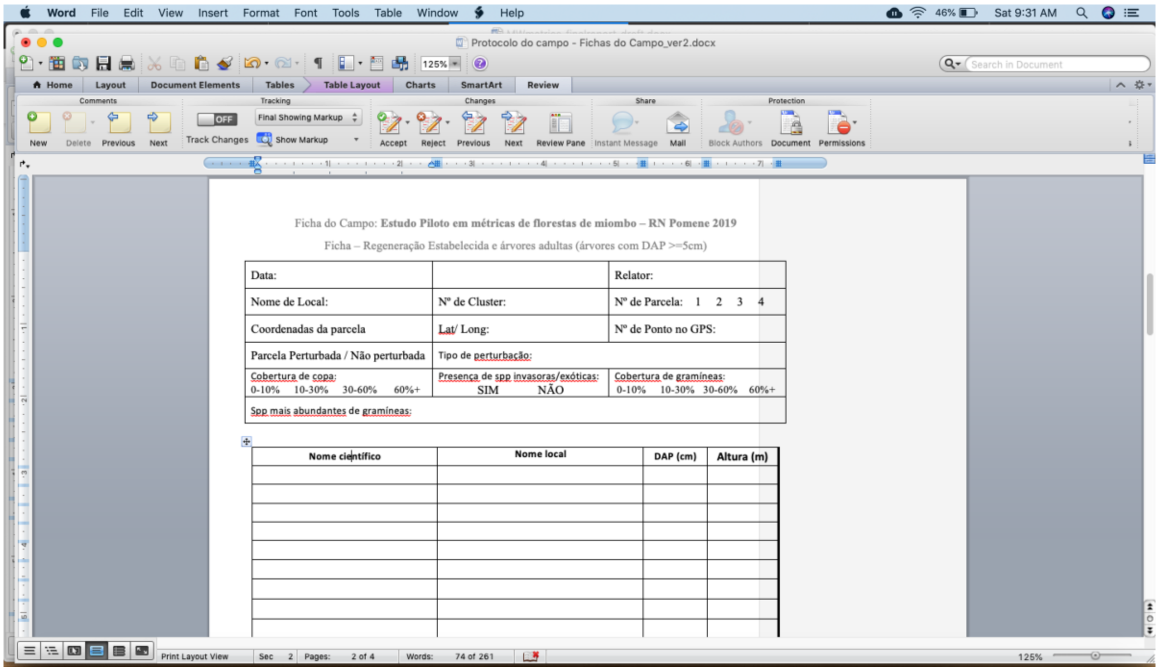
Em seguida, após a classificação do factor de intervenção humana (HQ5), a média aritmética da pontuação de cada *cluster* deve ser efectuada por forma a calcular a pontuação final.

**PASSO 4: Decisão sobre a condição ecológica**

A condição ecológica final de Miombo será interpretada da seguinte forma:

| Condição ecológica | Descripção | Valor final (%) |
|---|---|---|
| Boa | A componente arbórea está em boas condições se comparada com as referências nacionais e mais do que 1 indicador secundário está presente. | 60-100 |
| Média | A componente arbórea está em condições razoáveis se comparada com as referências nacionais e 1-2 indicadores secundários está presente. | 30-59 |
| Má | A componente arbórea está em condições más se comparada com as referências nacionais e nenhum dos indicadores secundários está presente. | <30 |

## Anexo 1: Exemplo da ficha de campo para colheita de dados dendrométricos no campo



Ficha do Campo: **Estudo Piloto em métricas de florestas de miombo – RN Pomene 2019**

Ficha – Regeneração Estabelecida e árvores adultas (árvores com DAP >=5cm)

| | | |
|---|---|---|
| Data: | | Relator: |
| Nome de Local: | Nº de Cluster: | Nº de Parcela: 1 2 3 4 |
| Coordenadas da parcela | Lat/ Long: | Nº de Ponto no GPS: |
| Parcela Perturbada / Não perturbada | Tipo de perturbação: | |
| Cobertura de copa: 0-10% 10-30% 30-60% 60%+ | Presença de spp invasoras/exóticas: SIM NÃO | Cobertura de gramíneas: 0-10% 10-30% 30-60% 60%+ |
| Spp mais abundantes de gramíneas: | | |

| Nome científico | Nome local | DAP (cm) | Altura (m) |
|---|---|---|---|
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# ANNEX V: Report of the Stakeholder workshop

**WORKSHOP REPORT**

**Rapid Assessment Tool for Miombo Conservation Forest State Workshop**

**Maputo, August of 2019**

***Project COMBO: Conservation, Mitigation Hierarchy and Biodiversity Offsets in Africa***

## Background

Over the last decade there has been a significant increase in the exploitation of natural resources in Mozambique as well as the development of infrastructure, which have resulted in a number of negative environmental and social impacts. Consequently, there is an urgent need to find ways to reconcile the economic development of Mozambique with the conservation of biodiversity and ecosystem services, upon which over 80% of the population directly depends.

A promising approach that has been used internationally to attempt to reconcile economic development and biodiversity conservation is the implementation by project developers of a *mitigation hierarchy* which requires them to avoid and minimize impacts, restore biodiversity and ecosystem services in impacted areas, where possible, and if significant but acceptable residual impacts persist, design and implement biodiversity offsets, according to an appropriate management plan, in order to achieve No Net Loss (NNL) or a Net Gain (NG) of biodiversity. A key driver for the adoption of this mitigation hierarchy was and remains compliance with environmental standards and guidelines established by financial institutions (e.g. IFC, World Bank, bilateral donors, etc.) and some sectorial associations (e.g. Equator Banks[3]).

There is a growing/increasing consensus around the NNL/NG goal in Mozambique, in the business sector as well as within key ministries such as the Ministry of Land, Environment and Rural Development (MITADER) and the Ministry of Mineral Resources and Energy (MIREME). It is seen as a valuable tool to mitigate negative impacts from large-scale and/or high-risk development projects and to attract investors committed to international best practices for biodiversity and ecosystem services management. Various private sector companies, particularly multinationals operating in the country, have expressed a clear commitment to such international best practice standards. A national compliance framework would assist investors in fulfilling their obligations to comply with the performance standards of financial institutions, while requiring the same level of environmental performance from all project developers. In 2016, the World Bank funded the development of a *RoadMap for a No Net Loss Aggregated System including Biodiversity Offsets for Mozambique* (Biofund, 2016). This roadmap continues to guide the development of policy and implementation options in the country.

However, measuring losses and gains in biodiversity is not straight forward due to its complexity and context-related variability. To enable measurement, proxies are often used (e.g. ecosystems or habitats that represent biodiversity more generally) and metrics are then

[3] 94 financial institutions in 37 countries have adopted the Equator Principles, including banks operating in Mozambique such as Standard Bank, Societé General, Barclays and Nedbank.

defined for these biodiversity features so that the amount of biodiversity loss from impacts and the amount gained from offsets can be quantified and compared to establish/assess/evaluate if NNL or NG are achievable and achieved. High levels of uncertainty inherent in quantifying biodiversity features, and changes over time in response to frequently complex sets of interacting drivers must be considered in constructing appropriate metrics (e.g. to build in defensible margins of error). At the same time, metrics have to be practical to enable measurement within reasonable timeframes and resources.

In this context, there is a need to determine how to measure the condition of ecosystems for Mozambique in a pragmatic way. For the Miombo woodlands in particular, a framework of ecological assessment is justified by the fact that it is the most extensive forest ecosystem in the country thus representing a significant portion of national biodiversity. On the other hand, this is a quite well studied ecosystem in the country and there exist national experts in Miombo. This set of conditions will facilitate the definition of a solid framework for the country, which will contribute to the establishment of appropriate metrics for the offsetting system in Mozambique. Given the country's limitations and specially the Miombo ecological variability it is important that this initial exercise focus on ecosystem condition, which is a challenging part of any robust metric and important for understanding / quantifying losses and gains.

## Objectives

- Metric approach applicability analyse
- Discuss and validate the national metric approach
- Analyse of inclusion of others indicators.
- 

## Methodology

The Validation of a Rapid Assessment Tool for Miombo Forests Conservation Status in Mozambique was held on the 19nd August 2019, at the Radisson Blu Hotel, in Maputo according to the agenda in Appendix I. This workshop is part of the expert consultation phase intended to integrate knowledge from experienced professionals in the country and abroad, to define metrics to determine biodiversity losses, as well as the gains from offset actions, so that they can be quantified and their equivalence can be compared.
The workshop was co-organized by the COMBO project led by WCS in Mozambique, BIOFUND and the Centre for the Study of Agriculture and Natural Resources Management (CEAGRE).
The meeting was attended by 23 participants (see participants list in Appendix II), among them flora and fauna expert, environmental impact assessment consultants, government representatives (Ministry of Land, Environment and Rural Development), private companies, research institute, academy, and NGOs, as illustrates in table 1 (
Appendix I II).
To achieve the objectives of the workshop, a combination of expository and participatory methods was used to provide information on the progress of the work and to gather contributions from the experts.

The workshop was divided in five moments, namely: Welcome remarks; Presentation of the proposed metrics and approach suggested; Discussion; working group on metric exercise and discussion and, plenary discussion.
The welcome remarks focused on the scope of the study, objectives and perspectives of the project, including the study about mangrove metrics definition.
The presentation focused on main process and activities used to develop the metric, which include desktop study about metric concept and international best practices; comparative analysis of four approaches applied in different countries; Presentation of case study in Inhambane province; comparative analysis of a case study data using four different approaches. After oral presentation the discussion focused on comments, questions, suggestions, etc. The following step was group exercise and discussion, where the participants were divided in four group whose task was scenarios analysis with different parameter from case study using Ambatovy approach.
After discussions, all four groups presented their discussions and time was given to all participants for comments, suggestions, questions, etc and this was the last moment of the workshop.

**Discussion**

*In the first section*

The presentation focused on Miombo importance related with its extension in the country forest area; Background about Metrics definition and approach around the World using examples from England, Germany, Australia and Madagascar; Case study for miombo metrics test in Mozambique realized in Inhambane province in South region of Mozambique; Performance of the different approach using data from case study; Suggestion about best approach and needed modifications

The discussion related with this presentation focused in the following issues:

- Possibilities of testing the Ambatovy modified approach using data from miombo of others districts in the country collected for the national forest survey.
- And the this is that is true but with some adjustments considering forest quality
- The need of definition of benchmark and possibilities of its use to compare with Management Plan
- The great advantage of Ambatovy Approach is related with few number of indicators and facility to measure and when the number of indicators is high it's no longer pragmatic.
- Possibility to integrate fauna indicators in the metrics analysis because it is an important component in the ecosystem functionality. The argument to not include this component was related with vulnerability to any factory and difficulties for measurement and define with type of fauna. And the method can become complex and less pragmatic so during the EIA process the EIA team must assess fauna quality so it can be used.
- The use of fauna as indicator is more complex because in some cases there are abundance of fauna in degraded areas and inverse in pristine forest.

- The need to clarify some concepts like degraded miombo, open and dense miombo and for this issue is necessary to consult national and international literature.
- The grass component could be a good indicator to differentiate open to dense miombo
- For the case study was used the number of trees, canopy cover, DBH, signal and intensity of human activities. This classification is made using satellite image but is validated with field work data
- The need of improvement of the methodology of differentiation of forest classes, and as it is not a concluded process more elements can be introduced to improve.
- The needs to clarify the human intervention because there are considerable number of forest with human intervention as cemetery, for example, but the forest is intact, so human presence cannot mean degraded forest....May be it can be considered as one of the indicators for Modified Ambatovy approach
- The degraded concept is related with the previous condition of the area before degradation...So is possible to find open and dense miombo both degraded. For the case its necessary to consider a historic information of the area in order to define whether is degraded or not.
- There is a need to clarify how the indicators will be used in monitoring process not only in baseline definition.
- The Biodiversity off set is related with reposition of what was lost and it is not regulated yet in Mozambique. It is only referred in the EIA regulation.
- Actually the EIA team identify different types of ecosystems, classify and describe how it will be impacted by the proposed project.
- It is important for now to define clearly the ecological condition so the following steps are not compromised and the main advantage of this process is the shift of pristine habitats on risk to degraded areas
- The last aspect was related with endemic species. How will it be considered in case are find in some of the classified areas which are potential for offsetting.

***In the Second section***

It was preceded by explanation about the exercise, related with case study data testing in Ambatovy approach and possibility of inclusion of other indicators in the original methodology.

After almost one hour of discussion in four group each one presented its findings and suggestion. After each presentation time was given for clarifications, doughty, questions, etc.

This was the sequence of the presentation:

Group #3

- Should be good to include human pressure in the method
- Possibility of increase of some weight to the variables
- How to analyze averages at national level
- When do we say that the averages are high
- Suggested to include more references and indicators

- Referred that the area is simpler to measure and objective
- Human pressure present good performance for some species so could be good indicator
- Fallow time could be one of the indicators in the metric.
- It's necessary to understand that in TFIA methodology fauna and human pressure are considered as indicators.
- As a country we must focus more in biodiversity and impact also think about initiatives integration.
- There is a need to think about how to conciliate with national forest inventory and use data collect in this context. There are some animal like guinea-pigs and monkey that are good indicators of agriculture areas.

**<u>Group #2</u>**

- The biomass of all Cluster of Case study area is under benchmark value.
- There are some cases of field data height that is bigger than benchmark.
- Needs to adjust the benchmark and ensure that the assessment is trustable. For example the height of the case study trees is shorter than inland areas trees.
- The idea is to define different benchmark for different areas and ecosystem.
- Should increase more indicators to represent the forest, however it must be pragmatic and not generalist.

**<u>Group #1</u>**

The benchmark value must be revised.
Data of miombo tree classes area not consistent, there are cases of disturbed miombo with more trees than dense miombo.
The benchmark must be according the vegetation type.
The vegetation classes were defined by specific composition not by number of trees. In some cases there are exotics and domestics species not native forest species.
Domestic species must be removed.

**<u>Group #4</u>**

- What is the meaning of % average. Why are we doing the average? Why not a scale/range? The average is for miombo species number.....
- There are some field data values above the benchmark. For the case we assumed the highest value as a benchmark and for those below the benchmark it remained the same.
- Need of inclusion of human pressure.
- Need to find a general benchmark for national level.
- Biomass is not a good indicator to include in benchmark because we don't have a standard allometric equation.

**Next steps**

- ✓ Degradation concepts definition

- ✓ Clarification of vegetation classes criteria's definition
- ✓ Analysis of inclusion of other indicators like fauna, human pressure, endemism, landscape quality, etc
- ✓ Definition of national metrics approach

# Appendix I. Agenda

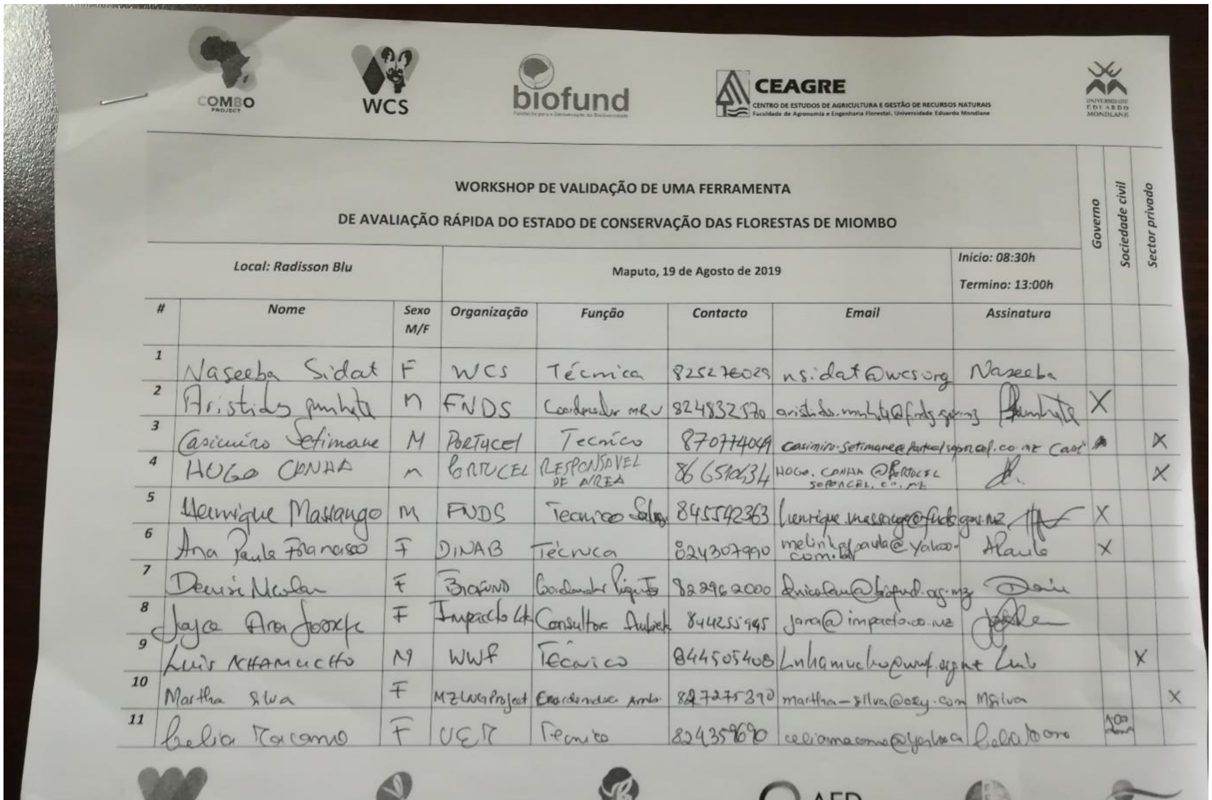
**WORKSHOP DE VALIDAÇÃO DE UMA FERRAMENTA**
**DE AVALIAÇÃO RÁPIDA DO ESTADO DE CONSERVAÇÃO DAS FLORESTAS DE MIOMBO**

| AGENDA | | |
|---|---|---|
| **19 de Agosto – Radisson Blu Hotel** | | |
| 8:30 | • Chegada dos participantes e registo | |
| 8:45 | • Introdução | WCS |
| 9:00 | • Apresentação do progresso do processo de desenvolvimento da ferramenta | Natasha Ribeiro |
| 9:45 | • Discussão | Todos facilitado pela WCS |
| 10:15 | • *Intervalo para café* | Todos |
| 10:30 | • Trabalho de grupo sobre a testagem das ferramentas | Natasha Ribeiro |
| 11:30 | • Apresentação e discussão | Todos facilitado pela WCS |
| 12:45 | • Notas de encerramento | WCS |
| 13:00 | • *Almoço* | Todos |

**Appendix II. Participants list**

| No. | Name | Gender | Organization | Sector |
|---|---|---|---|---|
| 1 | Alice Massingue | F | UEM | Academy |
| 2 | Ana Paula Francisco | F | DINAB | Government |
| 3 | AnicetoChaúque | M | UEM | Academy |
| 4 | Anselmo Gaspar | M | DINAB | Government |
| 5 | ArcanjoMurrube | M | IMPACTO Lda | Consulting company |
| 6 | Aristides Muhate | M | FNDS | Government |
| 7 | BernabéLanga | M | Verde Azul | Consulting company |
| 8 | Camila de Sousa | F | IIAM | Research institute |
| 9 | CasimiroSetimane | M | Portucel | Private company |
| 10 | CéliaMacamo | F | UEM | Academy |
| 11 | Denise Nicolau | F | BIOFUND | NGO |
| 12 | Eleutério Duarte | M | WCS | NGO |
| 13 | EsperançaChamba | F | IIAM | Research institute |
| 14 | Henrique Massango | M | FNDS | Government |
| 15 | Hugo Canha | M | Portucel | Private company |
| 16 | Joyce Ana Josefa | F | IMPACTO Lda | Consulting company |
| 17 | LourençoTsambe | M | AQUA | Government |
| 18 | LuísNhamucho | M | WWF | NGO |
| 19 | Martha Silva | F | MZ LNG Project | Private company |
| 20 | Naseeba Sidat | F | WCS | NGO |
| 21 | Regina Cruz | F | FNDS | Government |
| 22 | Sean Nazerali | M | BIOFUND | NGO |
| 23 | Tereza Alves | F | IIAM | Research institute |

## Appendix II. Participants list



COMBO PROJECT | WCS | biofund | CEAGRE – Centro de Estudos de Agricultura e Gestão de Recursos Naturais, Faculdade de Agronomia e Engenharia Florestal, Universidade Eduardo Mondlane | Universidade Eduardo Mondlane

WORKSHOP DE VALIDAÇÃO DE UMA FERRAMENTA

DE AVALIAÇÃO RÁPIDA DO ESTADO DE CONSERVAÇÃO DAS FLORESTAS DE MIOMBO

Local: Radisson Blu | Maputo, 19 de Agosto de 2019 | Inicio: 08:30h | Termino: 13:00h

| # | Nome | Sexo M/F | Organização | Função | Contacto | Email | Assinatura | Governo | Sociedade civil | Sector privado |
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| 10 | Martha Silva | F | MZLWG Project | Coordenadora Ambiental | 827275390 | martha-silva@ory.com | MSilva | | | X |
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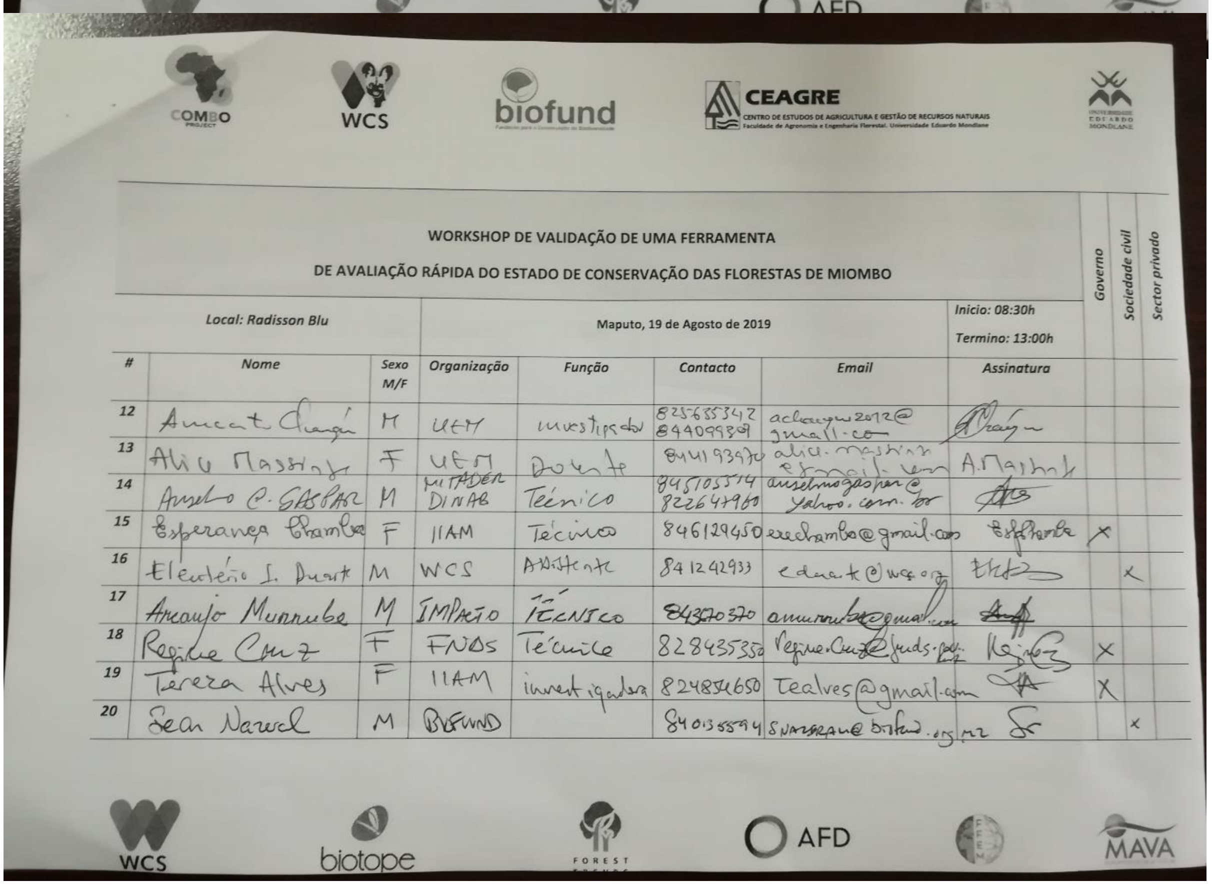

COMBO PROJECT | WCS | biofund | CEAGRE – Centro de Estudos de Agricultura e Gestão de Recursos Naturais, Faculdade de Agronomia e Engenharia Florestal, Universidade Eduardo Mondlane | Universidade Eduardo Mondlane

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| # | Nome | Sexo M/F | Organização | Função | Contacto | Email | Assinatura | Governo | Sociedade civil | Sector privado |
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| 20 | Sean Nazerali | M | BIOFUND | | 840135594 | snazerali@biofund.org.mz | [illegible] | | X | |

WCS | biotope | FOREST | AFD | FFEM | MAVA

WORKSHOP DE VALIDAÇÃO DE UMA FERRAMENTA

DE AVALIAÇÃO RÁPIDA DO ESTADO DE CONSERVAÇÃO DAS FLORESTAS DE MIOMBO

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| # | Nome | Sexo M/F | Organização | Função | Contacto | Email | Assinatura | Governo | Sociedade civil | Sector privado |
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| 23 | Lourenço Roberto [illegible] | M | AQUA | Técnico | 840501349 | [illegible]80@gmail.[illegible] | | | | |
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