REFOREST PROGRAMME POLICY BRIEFS – APRIL 2025

MOZAMBIQUE

Sustainable, Efficient and Profitable Use of Miombo Woodland Resources: A Case Study of Mozambique

Americo Manjate

Introduction, rationale and methodology

Miombo woodlands, is the largest tropical dry forests in Africa. It spans over seven countries, including Mozambique, and are vital for biodiversity, climate regulation and socio-economic development. However, rapid population growth, heavy forest dependence, and climate change have led to a 30% reduction in their coverage over the last four decades.

In Mozambique, Miombo woodlands cover decreased from 51% to 40% between 2007 and 2018, threatening the ecosystem's sustainability. Failure to reverse the current situation may lead to reduced biodiversity, altered hydrological cycles, increased soil erosion and increased greenhouse gases emissions, as well as decreasing carbon capture. Moreover, communities will be deprived of essential resources and their livelihood quality will deteriorate.

Degradation in the Miombo woodlands often results from selective logging practices, that harvest only selected species, and individuals above a minimum cutting diameter (MCD). This approach limits silvicultural practices that could protect and ensure the increase in the value of the remaining stand by removing individuals that pose a threat to it and by concentrating growth on the best individuals with the highest growth rates and wood quality. Moreover, by removing the best and more valuable trees, reduces the woodlands' value and genetic diversity, promoting its degradation or deforested to more profitable land uses.

Preference for certain species in the Miombo woodlands arises from the better knowledge of their management, wood properties and workability, as well as the ability to estimate their volumes and biomass. However, efforts have been made to extend research to dominant but lesser-known timber species such as *Brachystegia spiciformis* and *Julbernardia globiflora* aiming to enhance knowledge. Nonetheless, significant knowledge gaps remain, particularly regarding the current structure and composition of each stand, their degree of degradation, the ability to accurately and cost-effectively estimate their merchantable timber volume and biomass, as well as the yield outcomes and the impact on residual stands, for different harvesting methods.

Therefore, this study aimed at (1) describing the current stand structure and composition, (2) comparing the effects of silvicultural treatments on woodland structure and composition, (3) evaluating the material removed by each treatment, and (4) developing allometric equations for estimating total volume, biomass, component volumes, and volume ratios for *Brachystegia spiciformis* and *Julbernardia globiflora*.

To achieve those objectives, a silvicultural experiment was conducted in the LevasFlor concession in Mozambique. Simultaneously, 41 *Brachystegia spiciformis* trees and 23 *Julbernardia globiflora trees*, were felled and measured.

The experiment, involved fire management and silvicultural interventions. The fire management levels ranged from intensive management (with no wildfires) to no fire management (with high risk of fire). The silvicultural treatments involved selective logging, clearfelling with different diameters, thinning, sanitary cutting, pruning and a control treatment which was zero management interventions. Tree biomass, total merchantable volume and component volumes (branches and stems), and ratios of heartwood volumes to total and component wood volumes were modelled.

Key Findings and Policy Implications:

- Results show that the stand is degraded, as evidenced by the volume distribution of the most abundant and valuable species, that deviating from the typical inverted J-shaped curve. There is also a high abundance of *Combretaceae* family and *Millettia stuhlmannii species*, which are usually associated with degraded ecosystems. Such systems also have low density of commercial valuable species with diameters equal to or greater than the minimum cutting diameter (MCD), suggesting possible overexploitation.
- In terms of biomass and volume prediction in stands, species specific allometric equations were developed for individual trees of the two most abundant species of *Brachystegia spiciformis* and *Julbernardia globiflora*, based on DBH and total height. These equations enabled the prediction of total biomass, total merchantable volume, total heartwood, as well as the merchantable volume and heartwood of the stem and branches. Additionally, ratios were developed to determine the proportion of the stem relative to the total volume and the proportion of heartwood relative to the total volume for each component. The following equations were selected due to their best performance:

Table 1: Coefficients of the selected volume and biomass models by specie.

Models		
Brachystegia spiciformis		
Total tree merchantable wood	Stem merchantable wood	Branch merchantable wood

Models		
volume under bark (I)	volume under bark (II)	volume under bark (III)
$Y = 0.0000282 * (DBH^2 * Ht)^{0.994}$	**$Y = 0.0000431*(DBH^2 * Ht)^{0,946}$**	**$Y = 0.0000000000412 * (DBH^2 * Ht)^{1.992}$**
Total merchantable heartwood volume (IV)	Stem merchantable heartwood (V)	Branch merchantable heartwood (VI)
$Y = 0.0000000278 * (DBH^2 * Ht)^{1.558}$	**$Y = 0.00000003978 * (DBH^2 * Ht)^{1,515}$**	**$Y = 0.0000000000220E-11 * (DBH^2 * Ht)^{2.002}$**
Biomass of the total tree merchantable wood volume under bark	**Ratio of II vs I**	**Ratio of IV vs I**
$Y = 0.0000248 * (DBH^2 * Ht)^{0.976}$	**$Y = 0.996 - 0.00000134E-06*(DBH^2*Ht)$**	**$Y = -5.639 + 1.237*DBH$**
Ratio of V vs II		
$Y = -5.776 + 1.27*DBH$		
Julbernardia globiflora		
Total tree merchantable wood volume under bark (I)	Stem merchantable wood volume under bark (II)	Branch merchantable wood volume under bark (III)
$Y = 0.00000621 * (DBH^2 * Ht)^{1.198}$	**$Y = 0.00000804 * (DBH^2 * Ht)^{1.15}$**	**$Y = 0.000000170 * (DBH^2 * Ht)^{1.393}$**
Total merchantable heartwood volume (IV)	Stem merchantable heartwood (V)	Branch merchantable heartwood (VI)
$Y = 0.000000000000165 * (DBH^2 * Ht)^{2.711}$	**$Y = 0.000000000000129* (DBH^2 * Ht)^{2,722}$**	**$Y = 0.000000000000127 * (DBH^2 * Ht)^{2.529}$**
Biomass of the total tree merchantable wood volume under bark	**Ratio of II vs I**	**Ratio of IV vs I**
$Y = 0.00000480 * (DBH^2 * Ht)^{1.207}$	**$Y = 0.9 - 0.00254*(DBH2*Ht)$**	**$Y = 0.0000000340 * (DBH^2 * Ht)^{1.489}$**
Ratio of V vs II		
$Y = 0.0000000194*(DBH2 * Ht)^{1.554}$		

The silvicultural experiment demonstrated that selective cutting and the opening of gaps of 45 and 75 meters have different effects on the stand. Each treatment having the potential to promote the regeneration of different tree species, primarily based on their shade tolerance ability.

Policy Recommendations:

- It has been observed that woodland stands are degraded due to overexploitation of valuable commercial species. Thus, establishment through research and development (R&D), tax incentives, offering benefits to companies, communities and individuals that invest in research focused on the sustainable management, and use of lesser-known species will reduce pressure on overexploited commonly known valuable commercial species.
- Species-specific allometric equations were developed for the two most abundant Miombo species, namely *Brachystegia spiciformis* and *Julbernardia globiflora*. Policies promoting their use are necessary notably through creation of regulations that promote the trade of these species products with certification and traceability, and that discourage the exploitation of

overexploited species through increased taxes based on the volume harvested, potentially even prohibiting their exploitation depending on the species' status.

- The silvicultural experiment demonstrated that selective cutting and the opening of gaps promote the regeneration of different species. It is therefore encouraged to incorporate these alternative approaches (selective cutting vs. gaps) into the management plan while still maintaining continuous monitoring of the population fluctuations of each species within the stand.

Acknowledgement

I would like to extend my deepest gratitude to the REFOREST Program and the Swedish International Development Cooperation Agency (Sida) for their generous and unwavering support in making this research possible. The financial assistance and technical expertise provided were indispensable to the advancement of my research work, enabled me to achieve significant insights that will greatly contribute to the sustainable management and preservation of Miombo woodland resources. I am profoundly thankful for the trust and collaboration extended throughout the entire research process, which have been instrumental in ensuring the successful completion of this study.

Upgrading the durability of non-durable timber species using extractives-based formulations in Mozambique

Introduction and Justification

Over the past years, natural tropical forests in Mozambique have experienced rapid depletion due to the overexploitation of a few well-known timbers. The growing stock of well-known timber species such as *Afzelia quanzensis* Welw, *Milletia stuhlmannii* Taub and *Pterocarpus angolensis* DC has continued to decline in natural forests. In this context, harvesting the abundant lesser-used timber species is considered an alternative, although most are non-durable and demand further treatment. Nowadays, conventional wood preservatives are under restrictions worldwide due to their detrimental effect on human health and the environment. Increasing concerns exist about using oil-based preservatives (e.g. creosote) and waterborne-based (e.g. Chromated Copper Arsenate - CCA). Thus, there is an urgent need to address this challenge by developing environmentally friendly wood preservatives from naturally durable wood species extractives to treat the non-durable wood species, promoting them for use. The potential benefits of this solution are significant, offering a clue for the sustainability of Mozambique's forests. Indeed, natural wood preservatives could be suitable for processing non-durable and lesser-used timber species, prolonging their service life and relieving pressure on natural forests' most used timber species. Extractives such as natural wood preservatives are encouraged and attractive in the industry. Sawdust from durable hardwood species can be extracted using organic solvents and impregnated into the wood structure of less durable wood species. The main objective of this policy brief is to provide comprehensive information on the prospects of developing eco-friendly wood preservatives from naturally durable wood species extracts to treat non-durable and lesser-known timber species in Mozambique, potentially significantly enhancing the sustainability of the natural forests.

Key Findings

This policy brief is based on the research conducted in Mozambique following different stages, including sampling of non-durable wood species (*Brachystegia spiciformis, Julbernadia globiflora,* and *Sterculia appendiculata*), collecting sawdust from durable wood species (*Afzelia quanzensis* Welw and *Androstachys johnssii* Prain.) in local sawmills, removing extractives through Soxhlet and other laboratory means, chemically analyzing of extractives, formulation of the extractives using organic solvents and impregnation using a vacuum-pressure process (Figure 1).

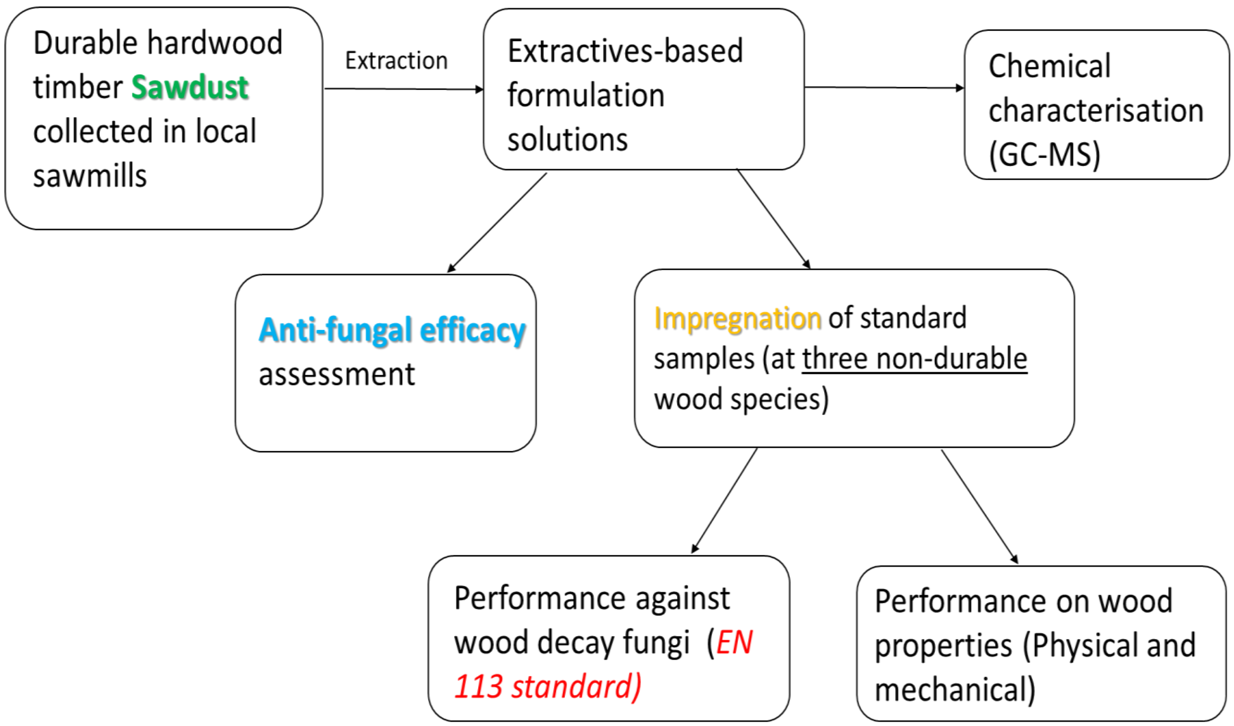

Figure 1: Stepwise development of eco-friendly wood preservatives

The study describes the prospects of using bioactive compounds from the abundant, durable hardwood timber sawdust accumulated in sawmills to formulate extractives-based solutions and treat emerging non-durable known and lesser-known/used timber species. The study results showed that the extractives-based formulation from *Afzelia quanzensis* and *Androstachys johnssii* hardwood timber sawdust restrained wood-destroying fungal activities. The chemical analysis of the hardwood timber sawdust extractives performed through the gas chromatograph technique revealed the presence of fatty acids and phenolic compounds exhibiting inhibitor effects on the fungal growth (*Coniophora puteana*, *Postia placenta*, *Lentinus lapideu*, and *Trametes versicolor*). For instance, extractives of both hardwood timbers are rich in palmitic (C16:0), oleic (18:1) and linoleic (C18:2) fatty acids, indicating a prospective anti-fungal effect. However, after treating the non-durable wood samples of

Brachystegia spiciformis, Julbernadia globiflora, and *Sterculia appendiculata* using formulations based on extractives from *Afzelia quanzensis* Welw and *Androstachys johnssii* Prain., the durability rating of all three non-durable wood species increased. The method used to impregnate and fix extractive formulation solutions to non-durable timber was efficient in minimal leaching. This could have been attributed to the interactions of functional groups of impregnated extractives with chemical components of non-durable wood. The extractive-based formulations proved to have the potential to upgrade the durability of non-durable timber, extending their service life.

Policy Recommendations

In order for the timber industry to take advantage of research finding, the role of forestry decision-makers is pertinent. To that effect the following recommendations are made:

- Develop extractive formulation solutions for treating non-durable timber from the accumulated sawdust in sawmills;
- Increase the volume of available durable timber by rendering non-durable timber durable thus minimizing the over-exploitation of durable timber. This strategy will contribute to maintaining forestry sustainability;
- Use of extractive formulation extracted from sawdust of durable hardwood timber in sawmills will protect non-durable timber with less detrimental effects on humans and the environment than synthetic chemicals;
- Use of extractive-based formulations to treat non-durable timber will add value to the group of non-durable timbers in natural forests;
- Minimize use of synthetic chemical preservatives to treat less durable timber;
- Wood extractive formulations obtained from renewable biomass, which makes them very sustainable and less costly than synthetic wood preservatives
- Effective fixing of the bioactive compounds from extractive-based formulations to non-durable timber also minimizes leaching and, therefore, protects the environment from chemical pollution.

Acknowledgement

Thanks to the Regional Research School in Forest Science (REFOREST), a PhD programme financed by the Swedish International Development Agency (Sida) through the Sokoine University of Agriculture (SUA) in Tanzania, Morogoro, that supported my research.

Enhancing Fire Management in the Miombo Woodlands of Central Mozambique

Osvaldo Meneses

Rationale

Wildfires are a critical ecological factor in the Miombo woodlands, influencing ecosystem processes and sustainability. However, their spatio-temporal patterns and impacts in Central Mozambique, specifically in the LevasFlor Forest Concession (LFC), remain poorly understood, posing risks to biodiversity, carbon storage, and long-term ecosystem stability.

These demonstrate significant ecological resilience to fires. However, variations in fire frequency influence plant species composition, density, and ecosystem dynamics, necessitating fire management to enhance biodiversity and long-term sustainability.

Wildfires significantly contribute to greenhouse gas (GHG) and aerosol emissions, impacting regional and global climate. The LevasFlor Forest Concession (LFC) in central Mozambique experiences frequent fires that release substantial emissions, emphasizing the need for effective management strategies.

Research was undertaken at LFC to investigate how best to enhance Fire Management, strengthen Miombo Woodland Resilience to fires and address Greenhouse Gas Emissions from Wildfires.

Research Findings

1. Fire Management in the Miombo Woodlands

- *Fire Incidence*: From 2001 to 2022, 88% of the LFC (46,000 ha) experienced at least one wildfire, burning an average of 9,733 ha annually (21% of the concession);
- *Fire Patterns*: Fires are most frequent and intense during September and October, predominantly in open and deciduous Miombo woodlands (74.4% of occurrences);
- *Fire Return Interval*: 84% of the area experienced moderate FRI (4–22 years), while 16% was affected by high to very high FRI (1–4 years);
- *Hotspot Regions*: Specific areas were identified as recurring fire hotspots, suggesting the need for targeted management.
- strengthen Miombo Woodland Resilience to fires

1. **Fire Frequency and Species Composition**

- Low Fire Frequency (LFF) supports higher seedling density and it is good for fire-sensitive species;
- High Fire Frequency (HFF) promotes greater seedlings diversity and favor fire-tolerant species and mature trees;
- Moderate Fire Frequency (MFF) balances diversity and density, supporting both fire-resistant and fire-sensitive species;
- *Structural and Biodiversity Metrics*:
    - 124 plant species identified across fire frequency clusters;
    - Dissimilarity had 72% variation in species composition among fire clusters;
    - Seedlings density differences was significant ($p < 0.005$) between LFF and other clusters;
- Key Species at Risk are *Brachystegia spiciformis* and *Julbernardia globiflora* were sensitive to fire and require targeted conservation measures.

2. **Greenhouse Gas Emissions from Wildfires**

- Total Emissions (2001–2022) was 1,601,082.98 tonnes of GHG and aerosols.
- Average Annual Emissions was 76,242.04 tonnes; and
- Seasonal Pattern: 75% of emissions occurred in peak wildfire months of September and October.

Implications

- Ecosystem Sustainability: Annual fire events, though of low frequency overall, pose a risk to the ecosystem's resilience and perpetuity.
- Greenhouse Gas Emissions: The potential contribution of these fires to GHG emissions remains unclear, necessitating further research.
- High fire frequency shifts species composition towards fire-adapted plants, potentially disrupting ecosystem dynamics.
- Moderate fire regimes enhance biodiversity and resilience, promoting balanced ecosystem productivity.
- Fire impacts vary by species, necessitating tailored conservation strategies for vulnerable and economically valuable species.

Recommendations

1. **Implement Cold Burning Strategies:** Promote controlled, low-intensity burns to reduce fuel loads and prevent destructive, high-intensity fires. Adopt Moderate Fire Regimes: Implement controlled fire strategies that balance diversity and density, ensuring ecological sustainability. In addition, strengthen efforts on fire suppression during peak months (September–October).

2. **Target Hotspot Regions:** Prioritize fire management efforts in areas identified as recurring fire hotspots to minimize fire outbreaks.

3. **Leverage Remote Sensing:** Utilize tools like MODIS burned area and active fire products to monitor and manage fire dynamics effectively.
4. **Further Research:** Investigate the ecological responses to varying fire frequencies and their impact on GHG emissions to inform sustainable management practices. Also, enhance fire monitoring and research to study cumulative effects of fire, climate change, carbon sequestration and soil factors on biodiversity and ecosystem services
5. **Prioritize Conservation of Key Species:** Focus on *Brachystegia spiciformis* and *Julbernardia globiflora* through early burning and silvicultural practices, such as vegetation maintenance around established seedlings.
6. **Promote Fire-Adaptive Management Practices:** Leverage natural fire-adaptive traits like high resprouting rates and thicker bark to strengthen resilience.

By Osvaldo Manuel Meneses (PhD candidate)
Sokoine University of Agriculture
Regional Research School in Forest Sciences program (REFOREST)
College of Forestry, Wildlife and Tourism
P.O. Box 3009 Chuo Kikuu, Morogoro, Tanzania.
Tel.: +258848381205; +258826485438

Email address: osvaldomineses@gm

Acknowledgement

Thanks to the Regional Research School in Forest Science (REFOREST), a PhD programme financed by the Swedish International Development Agency (Sida) through the Sokoine University of Agriculture (SUA) in Tanzania, Morogoro, that supported my research.