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ORIGINAL

Miombo woodland management and its ecosystem and social consequences in Missombo, Menongue, Angola

Gestión forestal del Miombo y sus consecuencias ecosistémicas y sociales en Missombo, Menongue, Angola

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ABSTRACT

Introduction: Miombo woodlands provide essential resources and ecosystem services to many communities in southern Africa, but intensive biomass extraction and agricultural expansion can alter woodland structure and regeneration capacity. Objective: To analyze social perceptions and ecosystem pressures associated with the management and use of Miombo forest resources in Missombo, Menongue, Angola. Methodology: A mixed-method field study with an exploratory-descriptive scope and concurrent triangulation design was conducted. From a reference population of 300 inhabitants, 55 participants were purposively selected: 50 community members, two traditional authorities, and three environmental technicians or social agents. A 12-item questionnaire, semi-structured interviews, and an observation form with eight indicators were used. Quantitative data were analyzed using absolute frequencies and percentages, while qualitative data were examined through thematic content analysis. Results: Charcoal was the most frequently used forest resource (38%), followed by firewood (31%). Charcoal production (47%) and agricultural expansion (29%) were the pressures most frequently identified. Ninety percent of participants reported not knowing the environmental regulation functions assessed. Conclusion: Sustainable Miombo management in Missombo requires integrating environmental education, economic alternatives, community regulation of forest use, and local monitoring of pressures on the woodland.

Keywords: Miombo woodland; sustainable forest management; charcoal; ecosystem services; Angola.

RESUMEN

Introducción: Los bosques de Miombo proporcionan recursos esenciales y servicios ecosistémicos a numerosas comunidades del África austral, pero la extracción intensiva de biomasa y la expansión agrícola pueden alterar su estructura y capacidad de regeneración. Objetivo: Analizar las percepciones sociales y las presiones ecosistémicas asociadas con la gestión y el uso de los recursos forestales del Miombo en Missombo, Menongue, Angola. Metodología: Se realizó un estudio de campo con enfoque mixto, alcance exploratorio-descriptivo y triangulación concurrente. De una población de referencia de 300 habitantes se seleccionaron intencionalmente 55 participantes: 50 miembros de la comunidad, dos autoridades tradicionales y tres técnicos ambientales o agentes sociales. Se aplicó un cuestionario de 12 preguntas, entrevistas semiestructuradas y una ficha de observación con ocho indicadores. Los datos cuantitativos se analizaron mediante frecuencias absolutas y porcentajes y los cualitativos mediante análisis de contenido temático. Resultados: El carbón vegetal fue el recurso más utilizado (38 %), seguido de la leña (31 %). La producción de carbón vegetal (47 %) y la expansión agrícola (29 %) fueron las presiones señaladas con mayor frecuencia. El 90 % manifestó desconocer las funciones de regulación ambiental evaluadas. Conclusión: La gestión sostenible del Miombo en Missombo requiere integrar educación ambiental, alternativas económicas, regulación comunitaria del aprovechamiento forestal y seguimiento local de las presiones sobre el bosque.

Palabras clave: bosque de Miombo; gestión forestal sostenible; carbón vegetal; servicios ecosistémicos; Angola.

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INTRODUCTION

The Miombo forests are one of the largest dry forest formations in southern Africa and are mainly distributed in Angola, Zambia, Tanzania, Mozambique, Malawi, Zimbabwe and the Democratic Republic of the Congo. They are characterized by the predominance of species of the genera Brachystegia, Julbernardia and Isoberlinia and by their adaptation to a marked climatic seasonality. Synthesis works on the Miombo have shown that its structure, composition and functioning are determined by the interaction between climate, soils, fire and human activities[1-3]. In addition to hosting high biological diversity, these forests store significant amounts of carbon in the biomass and soil, although the values vary according to the history of use, conservation status and environmental conditions[4].

The importance of Miombo extends beyond its ecological functions. In extensive rural and peri-urban areas, it is a direct source of energy, food, wood, construction materials, medicinal plants, honey, wild fruits, and other forest products. This dependence can account for a significant proportion of household income and livelihoods, particularly where few economic and energy alternatives exist[5-8]. In this sense, the forest functions as a socioecological system in which the conservation of vegetation cover and the well-being of communities are closely interrelated.

Pressure on these ecosystems has intensified due to the extraction of firewood and timber, charcoal production, agricultural expansion, and recurrent burning. Continued extraction can modify stand structure, reduce the presence of larger-diameter trees, and maintain forests in juvenile or degraded states[9]. Conversely, regeneration following slash-and-burn agriculture may require several decades to recover certain attributes of diversity, structure, and soil. Moreover, floristic composition may remain different from that of mature forests even after prolonged periods of abandonment[10].

In Angola, the relationship between forest harvesting and landscape transformation is particularly relevant. Recent studies conducted in the southwestern part of the country identified agriculture and charcoal production among the economic activities associated with the loss and degradation of Miombo and Mopane formations [11]. The assessment of areas subjected to selective cutting for charcoal showed that the recovery of structural variables increases with fallow age, although extraction modifies the dynamics of tree communities [12]. At the regional scale, analyses using satellite images have also documented simultaneous processes of agricultural expansion, canopy opening and closure, regeneration, and changes in woody vegetation, demonstrating that the dynamics of Angolan Miombo are spatially heterogeneous and respond to both human and ecological factors [13,14].

This complexity requires jointly considering the ecological and social dimensions of forest management. Recent evidence on Miombo ecosystem services shows a predominance of studies focused on forest products, wood fuels, raw materials, carbon, and soil quality, but also points to an uneven geographic distribution of research and the need to strengthen local studies that integrate biophysical and social indicators[15]. Community perceptions, their forms of resource use, and management alternatives proposed by local actors can provide complementary information for forest inventories and spatial analyses, especially in territories where systematic information remains limited.

In Missombo, municipality of Menongue, there remains a need for specific information on the forest resources used by the population, the activities recognized as the main sources of pressure on the forest, and local knowledge about their ecological functions. Understanding these relationships is relevant for guiding environmental education actions, community management, and monitoring of extractive activities, without disconnecting conservation from the economic needs of families.

In this context, the objective of the research was to analyze social perceptions and ecosystem pressures associated with the management and use of Miombo forest resources in the locality of Missombo, municipality of Menongue, province of Cubango, Angola. Specifically, the study sought to identify the main forest resources used by the local population, characterize the human activities recognized as sources of pressure on the forest, analyze community knowledge and perceptions regarding its ecological functions, and identify proposals aimed at sustainable forest management.

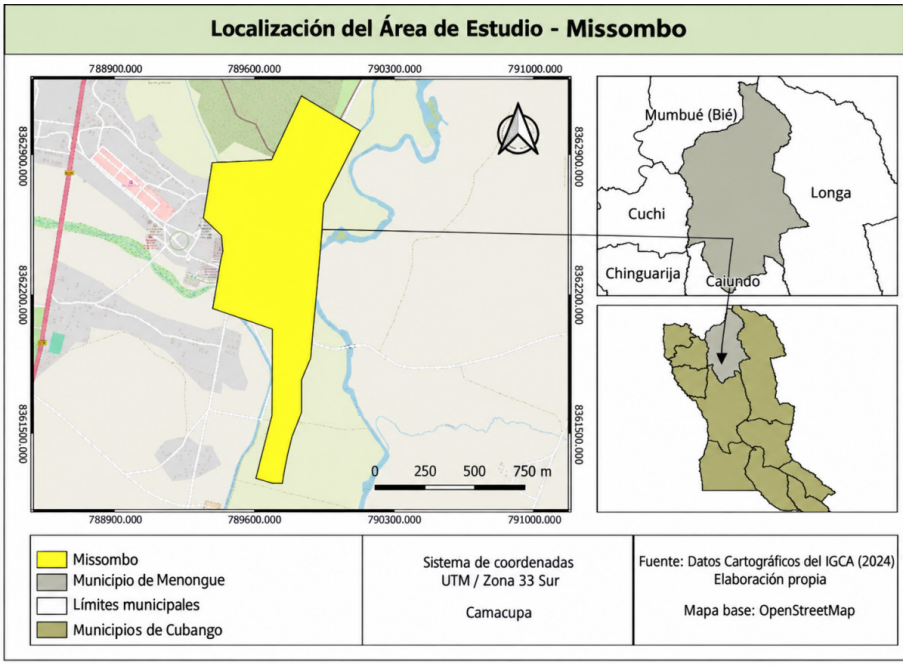
METHODS

A field study was conducted using a mixed-methods approach, an exploratory-descriptive scope, and a concurrent triangulation design. The quantitative component aimed to describe the use of forest resources, the main anthropogenic activities, and declared knowledge about certain

ecological functions of the forest; the qualitative component enabled a deeper examination of local actors' perceptions regarding environmental changes, causes of pressure, and sustainable management alternatives.

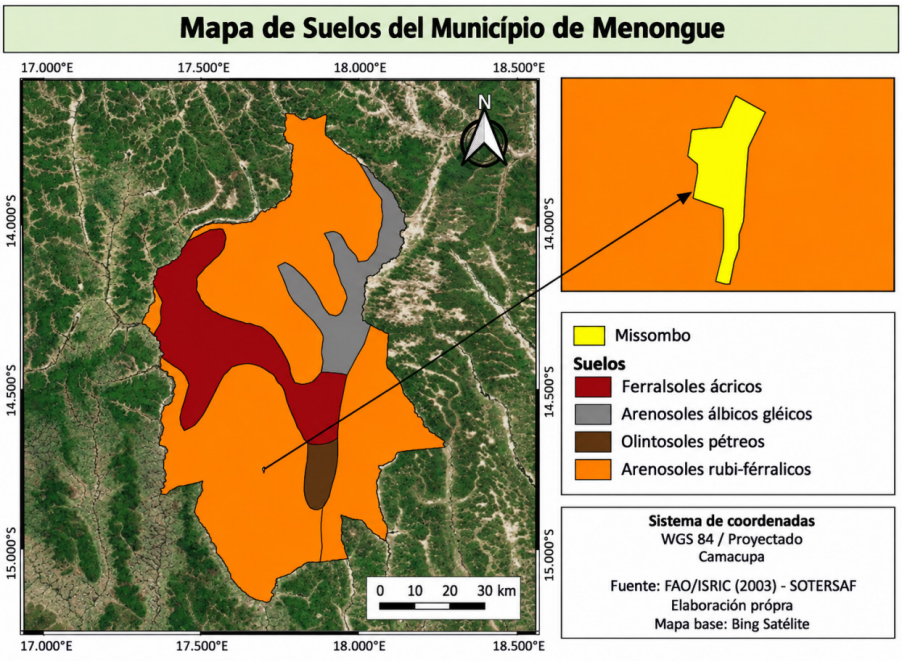
The study was conducted in the locality of Missombo, municipality of Menongue, Cubango province, Angola. The territorial delimitation and the location of the area were supported by cartographic information from the Instituto Geográfico e Cadastral de Angola16.

Figure 1. Location of the study area: Missombo



Source: own elaboration with cartographic data from the Instituto Geográfico e Cadastral de Angola [16].

Figure 2. Soil map of the municipality of Menongue and location of Missombo

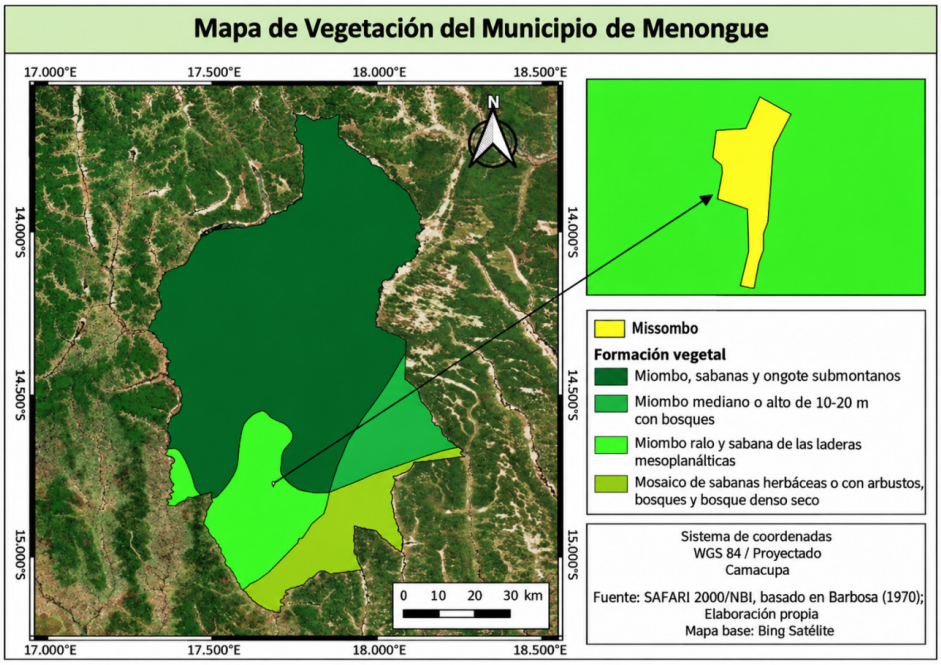


Source: Own elaboration based on FAO/ISRIC-SOTERSAF [17].

The edaphic characterization was based on the FAO/ISRIC-SOTERSAF17mapping. In the municipality of Menongue, Rubi-ferralic Arenosols predominate, with Acric Ferralsols, Albic Gleyic Arenosols, and Petric Plinthosols in specific sectors. These edaphic conditions are a relevant factor for interpreting productivity and vegetation regeneration processes.

The characterization of vegetation cover was based on the phytogeographic mapping of Angola by Barbosa18. The area falls within Miombo formations, savannas, and vegetation mosaics, with the presence of medium or tall Miombo and areas of herbaceous and shrub savanna.

Figure 3. Vegetation map of the municipality of Menongue



Source: own elaboration based on Barbosa [18] and SAFARI 2000/NBI.

The reference population consisted of 300 inhabitants residing in Missombo. A non-probabilistic purposive sampling approach was used, based on previously established criteria, through which 55 participants were selected. Individuals with more than 10 years of continuous residence in the locality and with direct or indirect dependence on local forest resources were included. Visitors, temporary residents, and people with less than 10 years of residence were excluded. The sample consisted of 50 members of the local community, 2 traditional authorities, and 3 environmental technicians or social agents.

The information was obtained through a survey, a semi-structured interview, and structured direct observation. The questionnaire consisted of 12 closed and open questions distributed across three dimensions: socioeconomic profile and use of forest resources; human activities related to degradation and deforestation; and knowledge of ecosystem services, perception of environmental alterations, and conservation proposals. Before its final application, a pilot test was conducted with five inhabitants who were not part of the final sample. Likewise, four specialists from the fields of biology, environmental sciences, ecology, and geography reviewed the instrument to assess the clarity, relevance, and linguistic appropriateness of the items.

The semi-structured interviews were conducted with the two traditional authorities and the three environmental technicians or social agents. They aimed to explore the perceived causes of forest degradation, the observed environmental changes, and possible community conservation alternatives. The interviews were conducted in person and lasted approximately 25 to 40 minutes. Direct observation was carried out using a structured form with eight indicators: presence of stumps from cut trees, active or inactive charcoal kilns, evidence of burning, soil erosion, natural regeneration, signs of hunting, firewood collection, and selective logging.

Data collection was conducted directly in Missombo. The questionnaires were administered in person, and the information was recorded on forms designed for the study. The interviews and field observation were conducted complementarily to compare the participants' statements with observable evidence in the territory. Subsequently, the data were organized and coded in a matrix for analysis.

Quantitative data were analyzed using descriptive statistics, with absolute frequencies and percentages. For the tables on forest resource use and anthropogenic activities, the consolidated total of 55 valid records was used as the basis. Qualitative data from open-ended questions and interviews were examined through thematic content analysis, based on reading the material, identifying units of meaning, coding, grouping into categories, and subsequent interpretation. The main categories were related to perceived environmental alterations, causes of pressure on the forest, barriers to conservation, and community management proposals.

The quantitative and qualitative components were integrated through concurrent triangulation. The frequencies of resource use and pressure activities were contrasted with the perceptions of authorities and technicians and with the evidence from direct observation. This procedure allowed joint interpretation of the social and environmental dimensions of Miombo use. Individual information was treated confidentially and was used exclusively for academic and scientific purposes.

RESULTS

The results indicate marked use of Miombo forest resources among participants from Missombo. Charcoal had the highest frequency of use, followed by firewood. Together, both resources accounted for 69% of responses, indicating the predominance of forest use for energy and subsistence purposes.

Charcoal accounted for 21 responses (38%), and firewood for 17 (31%). Medicinal plants accounted for 13%, while construction wood and wild fruits or honey each reached 9%. The distribution confirms the importance of woody products for the domestic economy and local energy supply.

Regarding the human activities identified as having the greatest impact, charcoal production had the highest frequency, followed by the expansion of shifting agriculture. Uncontrolled burning and the cutting of firewood and timber were also identified as pressures on forest cover.

Table 1. Main forest resources used by participants in Missombo

Forest resource used	Absolute frequency (n)	Percentage frequency (%)	Main purpose of use
Charcoal	21	38	Domestic energy and commercialization
Firewood	17	31	Cooking food and residential heating
Medicinal plants	7	13	Primary health care and traditional medicine
Construction timber	5	9	Construction of housing, fences, and artisanal furniture
Wild fruits and honey	5	9	Food supplement and seasonal income
Total	55	100	-

Note. Prepared by the authors based on field data.

Table 2. Main anthropogenic activities associated with impacts on the Miombo forest

Anthropogenic activity	Absolute frequency (n)	Percentage frequency (%)	Observed ecological consequence
Charcoal production	26	47	Selective felling of large trees and formation of canopy gaps
Expansion of itinerant agriculture	16	29	Loss of vegetation cover and impact on the soil organic layer
Uncontrolled burns	8	15	Impact on natural regeneration and young biomass
Felling of firewood and timber	5	9	Reduction of forest cover and habitat fragmentation
Total	55	100	-

Note. Authors' own elaboration based on field data.

Charcoal production accounted for 47% of the responses and was the activity most frequently identified as a source of pressure on the forest.

Agricultural expansion accounted for 29%, followed by uncontrolled burning with 15% and firewood and timber logging with 9%. During the observation, evidence compatible with these activities was recorded, including stumps, gaps in the canopy cover, burned areas, and signs of firewood extraction.

Regarding environmental knowledge and perception, limited recognition of the evaluated environmental regulation functions was identified. In addition, open-ended responses and interviews gathered perceptions about changes in local conditions and proposals aimed at strengthening community management.

Perceptions about extreme temperatures, droughts, and irregular rainfall should be interpreted as participants' assessments and not as instrumental measurements of climate trends. In the interviews, traditional authorities and environmental technicians agreed on the need to combine environmental education, community regulation of charcoal, and local forest monitoring mechanisms.

Table 3. Knowledge, environmental perception, and management proposals

Evaluated aspect	Result
Recognizes the environmental regulation functions considered in the instrument	10 %
States that he/she does not know these functions	90 %
Perceived environmental changes	Extreme temperatures, prolonged droughts, and irregular rainfall
Proposal 1	Strengthen continuous environmental education programs
Proposal 2	Disseminate the consequences of deforestation and regulate charcoal production at the community level
Proposal 3	Create local monitoring committees and promote sustainable community forest management

Note. Authors' own elaboration based on the questionnaires, interviews, and field records.

DISCUSSION

The results obtained in Missombo show a close relationship between the use of the Miombo forest and the energy and economic needs of the local population. Charcoal and firewood together accounted for 69% of the responses, a pattern consistent with the relevance of wood fuels and other forest products described for communities dependent on the Miombo5-8. The use of the forest, therefore, cannot be analyzed solely as an environmental pressure; it must also be understood as part of household subsistence strategies.

Charcoal production had twofold importance: it was the most frequently mentioned resource and, at the same time, the activity identified as the main source of pressure on the forest. In Angola, Kissanga et al. documented that charcoal production and marketing, together with agriculture, are associated with degradation processes and cover change in Miombo and Mopane formations11. In another study conducted in southern Angola, selective cutting for charcoal modified the structure and dynamics of tree communities, although recovery indicators increased with fallow age [12]. This coincidence reinforces the relevance of considering charcoal as a central component of forest management in Missombo.

The ecological importance of these pressures must also be understood from the perspective of biomass and carbon. Allometric models developed for tropical trees and specifically for Miombo formations show that changes in diameter, height, wood density, and stand structure are directly reflected in aboveground biomass estimates19,20. Studies conducted in Zambia have also shown that these forests store significant amounts of carbon in both aboveground and belowground biomass21. Although the present work did not conduct dendrometric inventories or estimate carbon, the presence of selective logging and clearings observed in the field justifies the need to incorporate these measurements in future research.

Agricultural expansion, identified by 29% of the participants, constitutes another relevant pressure. At the regional scale, land-use change, shifting agriculture, and wood extraction interact with other degradation factors. In Tanzania, Manyanda et al. pointed out that shifting agriculture, charcoal, firewood, timber, and fire are among the main drivers of tree and carbon removal in the Miombo22. In Angola, analyses by Loft et al. and Andrews et al. show a complex territorial dynamic

in which agricultural expansion, canopy opening, and regeneration can coexist spatially13,14. Therefore, the percentages obtained in Missombo describe the local perception of pressures, but they should not be interpreted as deforestation or land-cover change rates.

Uncontrolled burns accounted for 15% of the responses and were accompanied by observations of affected areas and alterations in regeneration. Fire is a historical ecological process in Miombo, but its frequency, intensity, and timing can modify forest structure and carbon balances. Modeling conducted in Miombo forests in Mozambique has shown that different fire regimes can reduce carbon storage capacity and that fire management is a relevant component of forest management23. This background supports the need to differentiate between the natural presence of fire and burning regimes associated with human activities.

The observations of erosion, loss of cover, and alterations in regeneration are also supported by studies on the effects of charcoal production. In Tanzania, Lulandala et al. found that larger clearings for charcoal production had lower infiltration capacity and lower soil organic carbon than systems with smaller-scale interventions24. These results show that the intensity and spatial configuration of harvesting can influence not only vegetation but also hydrological and soil functions. In Missombo, however, these consequences were recorded observationally and require specific measurements to quantify their magnitude.

Participants' perceptions of environmental changes must be interpreted with caution. Mentions of extreme temperatures, prolonged droughts, and irregular rainfall provide information about local experience, but the study did not include meteorological series or attribution analysis. Spatial research conducted in other Miombo landscapes shows that fire, agriculture, and land cover changes interact in a complex and variable manner across the territory25. Consequently, the perceptions obtained are useful for identifying community concerns and guiding research questions, but they do not in themselves constitute evidence of climatic causality.

Another relevant finding was that 90% of participants reported being unaware of the environmental regulation functions considered in the instrument. This figure does not imply a general absence of local ecological knowledge, since the same participants identified pressures, environmental changes, and management measures. It is more appropriate to interpret it as a gap in the explicit recognition of certain ecosystem services. The recent review by Manjate et al. highlights the need to integrate biophysical assessments with social and participatory approaches to understand the services of the Miombo more comprehensively [15].

The regeneration capacity of Miombo represents an opportunity, but it does not eliminate the risks arising from continued pressure. Muvengwi et al. observed structural changes between harvested and unharvested forests9, while Montfort et al. showed that certain diversity and soil attributes can recover over time, although composition and structure require prolonged periods10. Similarly, recent studies in the Democratic Republic of the Congo have documented natural regeneration potential even in anthropized habitats, conditioned by the intensity and recurrence of disturbances26. This background suggests that restoration and management strategies in Missombo should favor recovery periods and limit recurrent pressures on the same areas.

The proposals made by local actors—environmental education, community regulation of charcoal, and creation of monitoring mechanisms—are consistent with participatory approaches to Miombo management. However, their implementation should be accompanied by economic and energy alternatives, since restricting access to the forest without reducing household dependence can generate negative social impacts6,7. Sustainable management therefore requires combining conservation, community participation, improved efficiency in biomass use, and diversification of livelihoods.

The findings should be interpreted in light of the study's limitations. Sampling was non-probabilistic and purposive and was limited to 55 participants from a single locality; therefore, the percentages describe the sample studied and cannot be statistically generalized to the entire population of Menongue or Angola. Some of the results are based on perceptions and statements susceptible to recall and appraisal biases. Likewise, no systematic forest inventories, multitemporal analyses of satellite images, biomass measurements, quantitative edaphic variables, or meteorological records were carried out. Despite these limitations, triangulation between the survey, interview, and direct observation made it possible to identify local patterns relevant to guiding subsequent studies and community forest management actions.

CONCLUSIONS

The study made it possible to characterize the relationship between the use of forest resources

and the main perceived pressures on the Miombo forest in Missombo. Charcoal and firewood accounted for most responses regarding resource use, while charcoal production and agricultural expansion were identified as the activities exerting the greatest pressure. These results show that forest use is closely linked to the domestic and economic needs of the local population.

The limited recognition of the evaluated environmental regulation functions contrasts with the participants' capacity to identify changes in their environment and propose conservation measures. Therefore, environmental education actions should articulate local knowledge with technical information on ecosystem services, forest regeneration, and the effects of intensive use.

The sustainable management of Miombo in Missombo requires an integrated approach that combines community regulation of charcoal production, local monitoring of intervened areas, prevention of uncontrolled burning, promotion of more efficient carbonization technologies, and alternative income generation. These measures must be designed with community participation to prevent conservation strategies from becoming detached from the socioeconomic conditions that explain the daily use of the forest.

Finally, it is recommended that future research incorporate forest inventories, biomass and soil measurements, multitemporal land cover analyses, and local climate records, so that community perceptions can be contrasted with biophysical indicators and a more robust basis is available for assessing the evolution of Miombo in Missombo.

REFERENCES

1. Campbell BM, editor. The Miombo in transition: woodlands and welfare in Africa. Bogor: Center for International Forestry Research; 1996.
2. Chidumayo EN, Gumbo DJ, editors. The dry forests and woodlands of Africa: managing for products and services. London: Earthscan; 2010.
3. Ribeiro NS, Silva de Miranda PL, Timberlake J. Biogeography and ecology of Miombo woodlands. In: Ribeiro NS, Katerere Y, Chirwa PW, Grundy IM, editors. Miombo woodlands in a changing environment: securing the resilience and sustainability of people and woodlands. Cham: Springer; 2020. p. 9-53. https://doi.org/10.1007/978-3-030-50104-4_2
4. Bulusu M, Martius C, Clendenning J. Carbon stocks in Miombo woodlands: evidence from over 50 years. Forests. 2021;12(7):862. https://doi.org/10.3390/f12070862
5. Syampungani S, Chirwa PW, Akinnifesi FK, Sileshi G, Ajayi OC. The miombo woodlands at the cross roads: potential threats, sustainable livelihoods, policy gaps and challenges. Nat Resour Forum. 2009;33(2):150-159. https://doi.org/10.1111/j.1477-8947.2009.01218.x
6. Jew EKK, Burdekin OJ, Dougill AJ, Sallu SM. Rapid land use change threatens provisioning ecosystem services in miombo woodlands. Nat Resour Forum. 2019;43(1):56-70. https://doi.org/10.1111/1477-8947.12167
7. Ndenge TC, Perfect-Mrema J. Dependency, distribution and diversification (3Ds) of livelihoods in the Miombo woodlands: learning from Tanzania. Int J Sustain Dev World Ecol. 2022;29(5):429-439. https://doi.org/10.1080/13504509.2022.2032461
8. Lowore J. Understanding the livelihood implications of reliable honey trade in the Miombo woodlands in Zambia. Front For Glob Change. 2020;3:28. https://doi.org/10.3389/ffgc.2020.00028
9. Muvengwi J, Chisango T, Mpakairi K, Mbiba M, Witkowski ETF. Structure, composition and regeneration of miombo woodlands within harvested and unharvested areas. For Ecol Manage. 2020;458:117792. https://doi.org/10.1016/j.foreco.2019.117792
10. Montfort F, Nourtier M, Grinand C, Maneau S, Mercier C, Roelens JB, et al. Regeneration capacities of woody species biodiversity and soil properties in Miombo woodland after slash-and-burn agriculture in Mozambique. For Ecol Manage. 2021;488:119039. https://doi.org/10.1016/j.foreco.2021.119039
11. Kissanga R, Catarino L, Máguas C, Cabral AIR. Dynamics of land-cover change and characterization of charcoal production and trade in southwestern Angola. Remote Sens Appl Soc Environ. 2024;34:101162. https://doi.org/10.1016/j.rsase.2024.101162
12. Kissanga R, Catarino L, Máguas C, Cabral AIR, Chozas S. Assessing the impact of charcoal production on Southern Angolan Miombo and Mopane woodlands. Forests. 2024;15(1):78. https://doi.org/10.3390/f15010078
13. Loft T, Stevens N, Gonçalves FMP, Oliveras Menor I. Extensive woody encroachment altering Angolan miombo woodlands despite cropland expansion and frequent fires. Glob Chang Biol. 2024;30(2). https://doi.org/10.1111/gcb.17171
14. Andrews CA, Bowers S, Escobar-Alvarado LF, Collins K, Dexter KG, Ryan CM. Resilience, remoteness and war shape the land cover dynamics in one of the world's largest miombo woodlands. Trees For People. 2024;17:100623. https://doi.org/10.1016/j.tfp.2024.100623
15. Manjate H, Ribeiro N, Moreira F, Lomba A. Ecosystem services in miombo woodlands: challenges and opportunities to advance policy-relevant research. Trees For People. 2026;26:101406. https://doi.org/10.1016/j.tfp.2026.101406
16. Instituto Geográfico e Cadastral de Angola. Divisão Política e Administrativa de Angola. Luanda: IGCA; 2024.
17. Food and Agriculture Organization of the United Nations, International Soil Reference and Information Centre. Soil and terrain database for Southern Africa (SOTERSAF). Rome: FAO; 2003.
18. Barbosa LAG. Carta fitogeográfica de Angola. Luanda: Instituto de Investigação Científica de Angola; 1970.
19. Chave J, Réjou-Méchain M, Búrquez A, Chidumayo E, Colgan MS, Delitti WBC, et al. Improved allometric models to estimate the aboveground biomass of tropical trees. Glob Chang Biol. 2014;20(10):3177-3190. https://doi.org/10.1111/gcb.12629
20. Kuyah S, Sileshi GW, Rosenstock TS. Allometric models based on Bayesian frameworks give better estimates of aboveground biomass in the Miombo woodlands. Forests. 2016;7(2):13. https://doi.org/10.3390/f7020013
21. Handavu F, Syampungani S, Sileshi GW, Chirwa PWC. Aboveground and belowground tree biomass and carbon stocks in the miombo woodlands of the Copperbelt in Zambia. Carbon Manag. 2021;12(3):307-321. https://doi.org/10.1080/17583004.2021.1926330
22. Manyanda BJ, Nzunda EF, Mugasha WA, Malimbwi RE. Effects of drivers and their variations on the number of stems and aboveground carbon removals in miombo woodlands of mainland Tanzania. Carbon Balance Manag. 2021;16:16. https://doi.org/10.1186/s13021-021-00180-9
23. Ribeiro NS, Armstrong AH, Fischer R, Kim YS, Shugart HH, Ribeiro-Barros AI, et al. Prediction of forest parameters and carbon accounting under different fire regimes in Miombo woodlands, Niassa Special Reserve, Northern Mozambique. For Policy Econ. 2021;133:102625. https://doi.org/10.1016/j.forpol.2021.102625
24. Lulandala L, Bargués-Tobella A, Masao CA, Nyberg G, Ilstedt U. The size of clearings for charcoal production in miombo woodlands affects soil hydrological properties and soil organic carbon. For Ecol Manage. 2023;529:120701. https://doi.org/10.1016/j.foreco.2022.120701
25. Buramuge VA, Ribeiro NS, Olsson L, Bandeira RR. Exploring spatial distributions of land use and land cover change in fire-affected areas of Miombo woodlands of the Beira Corridor, Central Mozambique. Fire. 2023;6(2):77. https://doi.org/10.3390/fire6020077

26. Nghonda DDN, Muteya HK, Salomon W, Mushagalusa FC, Malaisse F, Ponette Q, et al. Floristic diversity and natural regeneration of Miombo woodlands in the rural area of Lubumbashi, D.R. Congo. Diversity. 2024;16(7):405. https://doi.org/10.3390/d16070405

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CONFLICT OF INTEREST

Does not exist.

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