Chapter 5

Biodiversity Studies in Key Species from the African Mopane and Miombo Woodlands

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Abstract

The Southern African Miombo-Mopane woodlands are globally considered as ecosystems with irreplaceable species endemism, being the most important type of vegetation in the region. Among the approximately 8500 plant species, legume trees play a crucial role in biodiversity dynamics, being also key socioeconomic and environmental players. From the ecological point of view, they contribute significantly to ecosystem's stability as well as to water, carbon, and energy balance. Additionally, legume species represent an immensurable source of timber and nontimber products. Research in Miombo-Mopane biodiversity has been mainly focused on the analysis of ecosystem drivers by means of ecological parameters and models, lacking interdisciplinary with relevant cross-cutting tools, such as the application of molecular markers to assess genetic diversity within the region. In this chapter, the applications and biodiversity dynamics of typical legume species from Miombo (*Brachystegia* spp., *Julbernardia globiflora*, and *Pterocarpus angolensis*) and Mopane (*Colophospermum mopane*) are reviewed. Gaps and challenges are also brought forward in the context of the lack of genetic diversity assessments and the need of an effective and coordinated network of interdisciplinary research.

Keywords: *Brachystegia* spp., *Colophospermum mopane*, *Julbernardia globiflora*, Miombo, Mopane, *Pterocarpus angolensis*, woodlands

1. Introduction

Africa has a vast array of indigenous legumes (Fam. Leguminosae or Fabaceae), ranging from small annual herbs to large trees [1]. The potential of native legumes for multipurposes is high but poorly exploited [2]. This is particularly the case of the woody species from the

Miombo-Mopane woodlands, one of the five ecozones (together with Amazonia, Congo, New Guinea, and the North American deserts) with irreplaceable species endemism [3]. Miombo is the most widespread and important type of vegetation in Southern Africa covering approximately 2.4 million km^2 across seven countries: Angola, Democratic Republic of Congo (DR Congo), Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe [4, 5]. Mopane extends over 0.48 million km^2 in Botswana, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, and Zimbabwe, constituting the second most important type of vegetation in the region [4]. The woodlands are the main source of woody species and a wealth of resources to the livelihood systems of millions of rural and urban dwellers that depend on these ecosystems to meet their food, health, energy, and housing needs [6, 7]. Environmentally, Miombo and Mopane add to biodiversity and have a global impact in energy, water, and carbon balances.

Miombo woodlands (**Figure 1A**) are dominated by legume trees belonging to three Caesalpinoideae genera: *Brachystegia* (Miombo in Swahili), *Julbernardia*, and *Isoberlinia*. On the contrary, Mopane woodlands (**Figure 1B**) are characterized by monospecific stands of *Colophospermum mopane* (Benth.) Léonard (also belonging to the Caesalpinoideae subfamily of legumes) [6, 8]. From the environmental point of view, these plants are determinant for energy, carbon, and water balance [9, 10]. At the socioeconomic level, Miombo-Mopane legumes are key providers of goods and services [11]. The woodlands are also very important to the national economies as they provide timber for exportation [5].

The ecological dynamics of Miombo-Mopane is strongly influenced by a combination of climate, disturbances (e.g., drought, fire, grazing, and herbivory primarily by elephants), and human activities [12, 13]. The growing population in the region over the last 20–25 years has resulted in increased woodlands degradation and deforestation. Slash-and-burn agriculture and charcoal production are the major causes of forest loss and degradation [14–16]. Additionally, the region is experiencing several major investments in mining, commercial agriculture, and infrastructures, which have further increased the pressure on the woodlands [17].

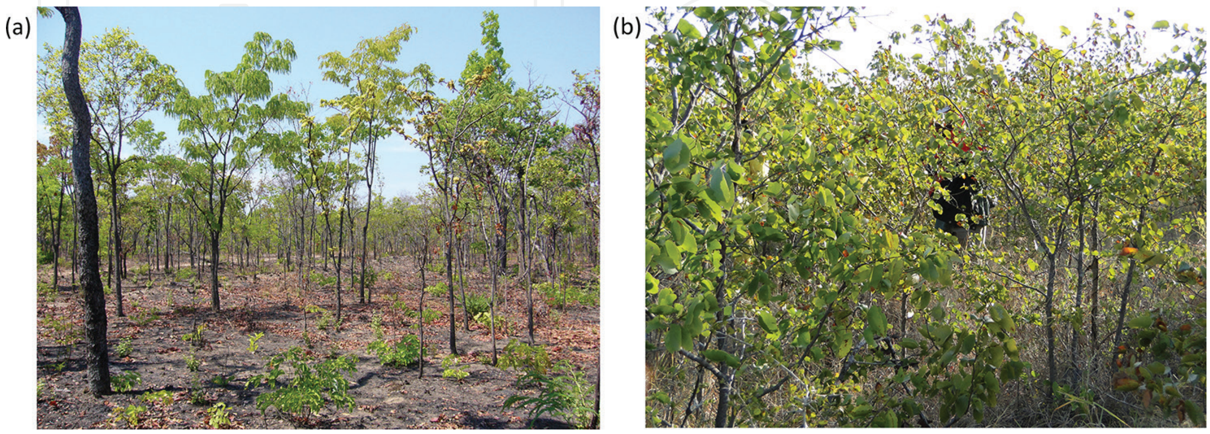

Figure 1. Images of Miombo and Mopane woodlands. (A) Miombo regrowth in burned area; (B) Shrub-like *C. mopane* specimens.

Changes in the global climatic pattern constitute another major threat for these ecosystems. They are mainly associated with more extreme wet and dry seasons as well as with extreme temperatures, which may change disturbance regimes (e.g., fire, shifting cultivation) and thus the prevailing biodiversity status [18–22]. For example, [19] predicts 5–15% reduction in precipitation for Southern Africa, while Green and coauthors [23] hypothesize that the combined effect of climate changes and disturbances may cause the loss of ca. 40% of the woodlands by the middle of the century. In line with these predictions, field studies combined with remote sensing and Geographic information system (GIS) methodologies indicated a decline in vegetation richness of 10–30% across Sahel and a southward shift of Sahel, Sudan, and Guinea zones due to shifts in temperature and precipitation regimes [21]. This may impose changes in biodiversity and biomass with associated modifications on the pattern of goods and services offered by the ecosystems. Under this scenario, several researchers are currently investigating (i) the impacts of the different ecosystem drivers on the woodland biodiversity, (ii) the capacity of biodiversity to supply and underpin goods and services, (iii) the patterns of genetic diversity of important species across environmental gradients, (iv) how different land cover types affect the existing patterns of biodiversity, and (v) how the changes in biodiversity will affect the availability and accessibility of resources to rural and urban dwellers.

In this review, we present the current efforts, gaps, and challenges toward biodiversity conservation of key legume trees from the Miombo and Mopane woodlands, respectively: *Brachystegia* Benth., *Julbernardia globiflora* (Benth.) Troupin, *Pterocarpus angolensis* DC. (Miombo), and *C. mopane* (Mopane).

2. Brief description and major applications of typical Miombo-Mopane species

2.1. *Brachystegia* spp. (subfamily Caesalpinioideae)

Brachystegia (Miombo) is a large genus of trees confined to tropical Africa, representing major components of deciduous (Miombo) woodlands of central and Southern Africa. This is a taxonomically difficult genus, since some species hybridize freely with others, making classification difficult [24]. The most frequent species in dry Miombo woodland are *Brachystegia boehmii* and *Brachystegia spiciformis*. *Brachystegia* species are generally slender and graceful with a clean bole, a crown of handsome delicate leaves (**Figure 2A**) and a fibrous stem bark. The genus as a whole is noted for the great range of red colors of the young foliage, later turning into various shades of green [24]. *Brachystegia* species play an important role in formal and informal economies in the region. For example, barks, which are particularly fibrous, are commonly used for construction, being especially favored for weaving, fishnet, beds, and rope making. Bark is easily peeled from a number of species and is used for fabricating beehives. The ash is used as fertilizer in shifting cultivation, and the wood is used for domestic tools, canoes, firewood, and charcoal; timber is usually heavily susceptible to borers but when treated is suitable for several purposes [6, 25]. *Brachystegia* is also an important nectar-producing genus for apiculture [26]. Additionally, several species of *Brachystegia* are

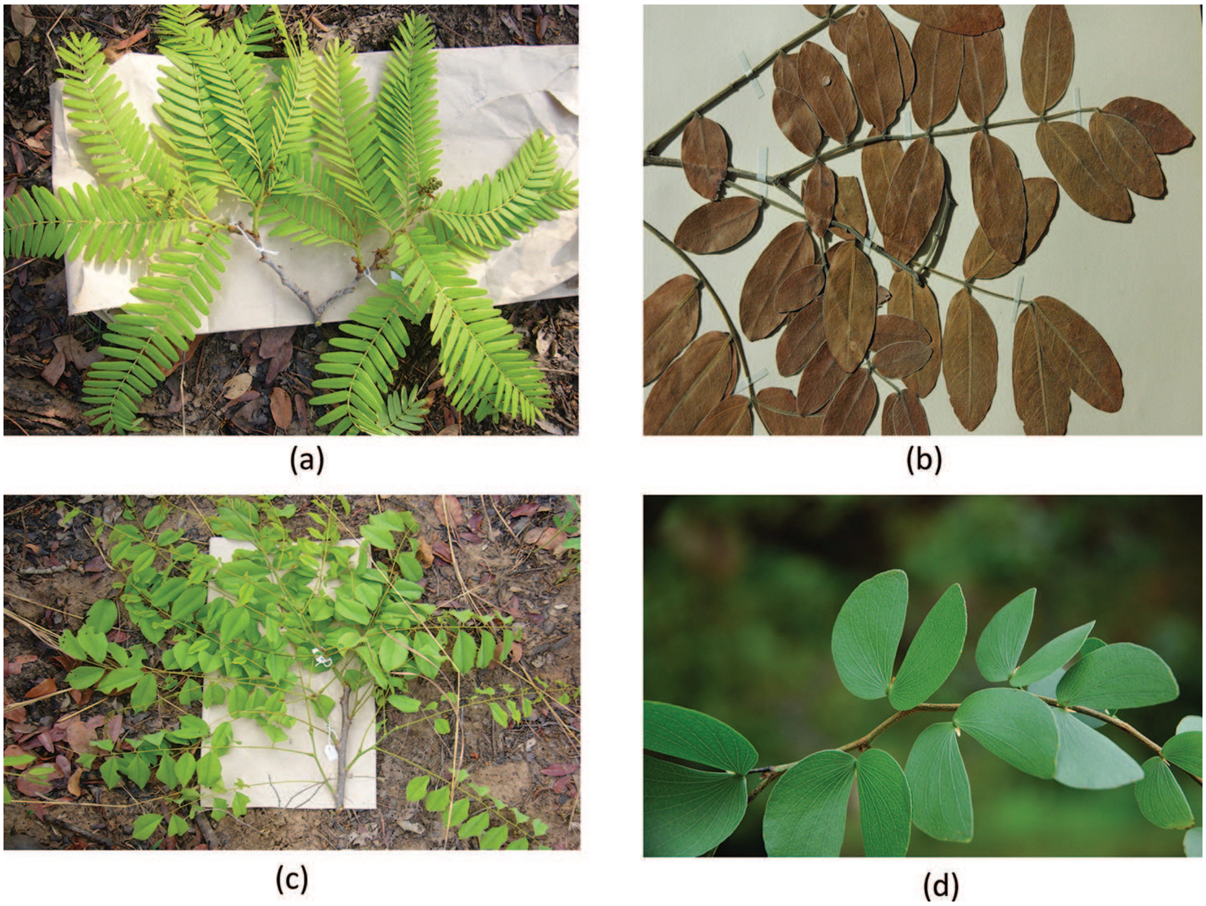

Figure 2. Details of the leaves from (A) *Brachystegia boehmii*, (B) *Julbernardia globiflora* (Barbosa and Carvalho, 2825, 1949 LISC Herbarium), (C) *Pterocarpus angolensis*, and (D) *Colophospermum mopane* (B and D credits to Maria Cristina).

used in traditional medicine [27–29], with antimicrobial, anti-inflammatory, and antidiabetic activities (**Table 1**) [30–32].

2.2. *Julbernardia globiflora* (subfamily Caesalpinioideae)

J. globiflora, known as Mnondo [6], is a common species of sandy woodlands, often codominant with *Brachystegia* species. It is distributed from DR Congo, Burundi, and Tanzania southward to Botswana, Zimbabwe, and Mozambique [33]. *J. globiflora* is usually recorded as a small- to medium-sized deciduous tree with a rounded crown that can grow up to 18 m in height, with alternate and compound leaves (**Figure 2B**) and thick fire-resistant bark [6]. Like *Brachystegia* species, *J. globiflora* is a useful local source of timber and nontimber products. The wood is hard, with a heartwood resistant to borers, and is widely used as a general-purpose timber and also for the construction, tool handles, mortars, and canoes as well as fuelwood and for making charcoal [24, 25, 33]. Ropes, fishnets, and other items are made from the bark fiber, which is fairly good, although of poorer quality than that of the *Brachystegia* spp. [6]. The bark yields tannin used for dyeing [33]. The tree is an important fodder species for early-season browsers [34]; it is also a bee forage, yielding honey of very high quality. Together with *B. boehmii*, *J. globiflora* is among the most important hive trees and nectar sources [26]. The leaves of *J. globiflora* are important food for edible caterpillars [33]. Although roots, barks, and leaves

Species	Phytochemical and pharmacological studies	Genetic diversity studies
Brachystegia boehmii Taub.	Leaves: antibacterial [30]	ISSR markers [70]
	Leaves: anti-inflammatory [32]	
Julbernardia globiflora (Benth.) Troupin	No studies reported	
Pterocarpus angolensis DC	*Antischistosomal* [90]	RAPD [79, 80]
	Stem, stem bark, leaves: anthelmintic [40]	
	Seeds: antibacterial [91]	
	Stem bark: antibacterial and anti-inflammatory; lack of mutagenicity [92]	
	Stem bark, leaves: anthelmintic, antibacterial, and cytotoxic [41]	
	Antibacterial [93]	
	Stem bark: antibacterial; epicatechin and derivatives identified [37]	
	Stem bark: antibacterial; leaves, stem bark: antifungal, HIV-1 reverse transcriptase inhibitory [38]	
	Leaves, stem bark: anti-inflammatory [94]	
	Stem bark, roots: antibacterial; tannins and saponins identified [39]	
Colophospermum mopane (Benth.)	Bark and seeds: significant cytotoxicity against a human breast cancer cell line [48] Heartwood: mono-, di-, and triflavonoids; leaves: beta-sitosterol and stigmasterol; aerial part: essential oils that comprise mainly alpha-pinene and limonene; bark and seeds: diterpenes, including dihydrogrindelaldehyde [48]	Allozyme markers [83]
	Seeds: anti-inflammatory and antioxidant activities [95]	
	Bark and seeds: significant cytotoxic activity against a human breast cancer cell line (aldehyde) [96] Bark and seeds: three new diterpenes isolated [96]	
	Oligomeric flavonoids [97]	
	Leaves: antimicrobial activity [49] Seed husks and leaves: five labdane (1–5), an isolabdane (6), and five clerodane diterpenoids (7–11) [49]	

Table 1. Phytochemical, pharmacological, and genetic diversity studies on the tree species *Brachystegia boehmii* Taub., *Julbernardia globiflora* (Benth) Troupin, *Pterocarpus angolensis* DC., and *Colophospermum mopane* (Benth).

of *J. globiflora* have been recorded to be toxic, various plant parts are used in traditional medicine, mainly externally to treat ailments such as snake bites, leprosy, and conjunctivitis [28, 33].

2.3. *Pterocarpus angolensis* (subfamily Papilionoideae)

P. angolensis (commonly known in English as bloodwood, kiaat, and African teak) [6] is a medium-sized to large-sized tree up to 16 m in height but reaching 20 m under ideal conditions with a spreading crown and a single trunk. *P. angolensis* is widespread in southern tropical Africa, from Angola, DR Congo, and Tanzania south to northeastern South Africa and Swaziland [35]. The bark is dark gray to brown, rough, and longitudinally fissured. The drooping leaves have 5 to 9 pairs of subopposite to alternate leaflets (**Figure 2C**). The flowers are orange-yellow in large, branched sprays. The fruit is a very distinctive, indehiscent, and circular pod holding 1–2 small seeds [24]; the leaves are browsed by elephant and kudu; and fruits are eaten by baboons, monkeys, and squirrels [6]. *P. angolensis* serves a number of purposes, both utilitarian (as multipurpose timber, dye, forage) and in African folk medicine. It is the main Miombo and one of the most valuable timber trees in Africa heavily sought after for export and local use. The heartwood is golden or reddish brown, makes high-quality furniture, shrinks very little in drying, and is very resistant to borers and termites [24]. The wood is also used for construction, carpentry, flooring, boats, and wood carving. It is occasionally used for firewood [35]. The sap from the wood makes a permanent red stain on clothing and can be used as a dye. The powdered red inner bark of the roots, mixed with fat, is used to anoint bodies and faces by some ethnic groups in northern South-West Africa [6]. Traditionally, all parts of the plant are used for human and animal health purposes. For example, the bark is used as a powerful astringent to treat diarrhea, heavy menstruation, nosebleeding, headache, stomachache, schistosomiasis, sores, and skin problems; the root is believed to cure malaria, blackwater fever and gonorrhea [6, 24, 28, 35, 36]. Research studies reveal promising results concerning their antibacterial [37–39], antifungal [38], anthelmintic [40, 41], and HIV-1 reverse transcriptase inhibitory properties [38] (**Table 1**). At the environmental level *P. angolensis* is able to establish nitrogen-fixing symbiosis with rhizobium bacteria and therefore relevant for soil fertilization. It is also planted for soil conservation, for dune fixation, and as live fencing [35]. Flowering trees are good sources of pollen and nectar [35].

2.4. *Colophospermum mopane* (subfamily Caesalpinioideae)

C. mopane is the single species in the genus *Colophospermum*, which only occurs in Africa, being characteristic of hot and dry river valleys, where it is often dominant and may form almost pure stands over large areas—the "Mopane woodlands" [42]. Commonly known as mopane, it is widespread in Southern Africa, where it occurs in Zambia, Malawi, southern Angola, northern Namibia, northeastern Botswana, Zimbabwe, southern Mozambique, and northern South Africa [43]. Mopane is adapted to a wide variety of soils and temperatures, presenting different growth forms, from shrub-like to tall slender trees. It is deciduous or sometimes semideciduous, as water availability determines leaf drop [44], with beautiful autumn and spring colors. The highly sclerophyllous compound leaves (**Figure 2D**) have two leaflets, large and butterfly-shaped, which fold together in the hottest time of day [6]. Leaves and fruits are very glandular and smell strongly as turpentine. As a fodder species, mopane is vital in areas of low rainfall. Like most Miombo legume species, *C. mopane* is a true multipurpose tree, not only important for its wood but also as source of medicine, forage, and edible caterpillars [43]. Cattle and wild animals browse the foliage eagerly and sometimes eat the dry leaves and seeds from the ground [6]. Seeds are consumed by humans as famine food [43]. Mopane heartwood is very hard, and it is known to be very durable and resistant to insect damage. It is traditionally used for posts and poles in the construction of houses and palisade

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fences. Mopane wood accounts for more than 90% of the wood used for living and storing huts in large parts of Southern Africa [43]. It is suitable for flooring and for carving and is excellent for turned objects, and to a lesser extent, due to its weight and hardness, it is used for joinery and furniture. Mopane gives excellent firewood and makes high valuable charcoal [43]. The rough bark is used to make twine and for tanning [6, 43]. Larvae of mopane moth (*Gonimbrasia belina*) feed on the mopane leaves. Those large caterpillars are rich in protein and considered a local delicacy [6]. Mopane worms are also traded to generate income providing a good economic return [45]. The tree also acts as a food plant for a wild silk moth (*Gonometa rufobrunnea*). Cocoons of the moth are harvested as wild silk and processed to make cloth [43]. *C. mopane* is an important medicinal species, and different parts of the plant are used in the preparation of traditional remedies [43, 46, 47]. Research into Mopane-active compounds revealed biological activities with potential for human and animal health [48, 49] (**Table 1**).

3. Diversity and population structure studies

Miombo and Mopane woodlands face major threats related to climate, human, and animal pressure which in the midterm may reduce tree species abundances and, thus, ecosystem services [17, 43, 50]. Thus, understanding the interaction between the main woodland's drivers is crucial for the development of effective and sustainable management strategies for biodiversity conservation and resource use. In this section we focus on diversity and structure of the key legume trees referred above, i.e., *Brachystegia* spp., *J. globiflora*, *P. angolensis*, and *C. mopane*.

In the Niassa National Reserve (NNR), one of the most pristine and least disturbed areas of Africa's deciduous Miombo woodlands, notable alterations in vegetation structure and composition were reported in areas with high fire (mostly anthropogenic) frequency [51, 52]. These included a decrease in woody parameters and a replacement of typical Miombo species (*J. globiflora* and *Brachystegia* spp.) by subdominant species (*Combretum* spp., *Terminalia sericea* Burch. ex DC, and *Diplorhynchus condylocarpon* (Muell. Arg.) Pichon [51]. In southwestern Tanzania, [50] reported a tree species diversity score (Shannon-Wiener diversity) of 3.44 *versus* 2.86 in the Miombo woodlands subjected to low and high rates of resource use, respectively. In areas of moderate resources utilization, tree diversity was maintained, but the structure of the vegetation showed a reduction of Class 1 (diameter at breast height (DBH) < 10 cm) trees, indicating low recruitment. Key Miombo species from the genera *Brachystegia* and *Julbernardia* were present in all sites, but the frequency of the former declined by 60% from low to high utilization sites. The resilience of *Julbernardia* spp. to disturbances might be due to vigorous resprouting after cutting as observed in *J. globiflora* [33]. On the other hand, *P. angolensis* adult trees were harvested throughout the study site, and only immature specimens were recorded, suggesting that it is commercially extinct for the foreseeable future [50]. *P. angolensis* is widespread in many parts of Southern Africa; however, overexploitation endangers natural populations in all countries. None of the four species considered in this paper is listed in the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora Appendices. Only *P. angolensis* is reported by the International Union for Conservation of Nature (IUCN) as being near threatened. Technically, it does not meet the Red List criteria of a vulnerable or endangered species, but is close to qualifying for vulnerable [53].

Despite the factors referred above, natural factors, i.e., soil fertility, topography, and local hydrology, are also important determinants of biodiversity variation, although these factors are less studied [54, 55]. The vulnerability of the woodlands to climate changes is particularly high [19]. Species distribution models developed for *P. angolensis* under two different climate change scenarios suggest that potential and realized distributions are very similar in Southern Africa, except for Madagascar where the species could grow but does not occur, and that species distribution may be particularly threatened in Namibia and Botswana [56]. Accordingly, pollen records from *Brachystegia* spp. suggest a retraction of Miombo in *ca.* 450 km over the past 6000 years [57] and that such changes in population dynamics may be associated with shifts in temperature and moisture regimes [7]. Based on the historical range shifts in *B. spiciformis*, an ecological niche retraction of ca. 31–47% in the continuous Miombo woodlands from Zimbabwe and southern Mozambique was predicted by 2050 [58]. However, considering the resilience of *B. spiciformis* to extreme environments (e.g., low precipitation, high temperatures), such retraction may be less exaggerated than the model predictions, which no account with genetic adaptation [58].

Contrary to Miombo, Mopane woodlands are constituted by nearly monospecific stands of *C. mopane* [59], resulting in extensive areas with low compositional and structural diversity [60]. Due to the same factors mentioned for the Miombo woodlands, some parts of Southern African Mopane woodlands are experiencing a decline in natural stands [43]. For example, [61] analyzed the effects of heavy land utilization (mainly grazing) on vegetation structure communal woodlands of the Mopane Bioregion of South Africa. The authors observed prominent effects in plant structure, i.e., reduced canopy and height, transforming the woodland into a shrubland. A significant decrease in biomass in post–boom charcoal production in southern Mozambique was also reported [62]. Govender et al. [63] analyzed the effect of two fire management strategies in one of the most important areas of mopane, the Great Limpopo Transfrontier Park (GLTP), which crosses two countries: South African component Kruger National Park (KNP) and Mozambique Limpopo National Park (LNP). KNP has a very structured and intensive fire management (FM), while in LNP, the fire regime is unstructured and highly associated to the large number of people living within its limits. Even so, in LNP natural fire frequency did not affect the ecological weight of Mopane, whereas in the KNP, frequent managed fires reduced the ecological value in 100–200 [63]. These results indicate that natural fire regimes are important to maintain the ecosystem's equilibrium. Although less studied, *C. mopane* biodiversity shifts may also be affected by the environmental conditions. Stevens et al. [60] used MAXENT modeling to investigate which environmental variables may determine the distribution limits of *C. mopane* within Southern Africa. According to the results, both nonclimatic (dryness or hours of light) and climatic (temperature) variables may limit the regional distribution of *C. mopane*, which is restricted to warmer sites.

Genetic diversity is the basis for stability and survival under the ever-changing environments. Populations with high levels of genetic variation offer a diverse gene pool from which breeding and conservation programs can be designed. The over exploitation of the reported species may threaten their genetic diversity in the future and hence might limit their ecological and evolutionary development. Therefore, genetic diversity and structure studies are of utmost importance for designing appropriate conservation strategies.

The use of molecular markers constitutes an effective approach to evaluate genetic variation within and between species and populations, because they are expedited and precise and are not affected by the environmental processes. Polymerase chain reaction (PCR)-based markers, like random amplified polymorphic DNA (RAPD), Amplified fragment length polymorphism (AFLPs), inter-simple sequence repeats (ISSRs), simple sequence repeats (SSRs), or single-nucleotide polymorphisms (SNPs), are commonly used in plant science for a wide variety of purposes such as genome mapping, gene tagging, phylogenetic analysis, taxonomy, marked-assisted selection, and genetic diversity studies [64–73]. However, the analysis of the genetic variation and structure is an incipient issue in Miombo and Mopane research. Regarding the species selected for this review, up to our best knowledge, only four reports are available in the scientific literature (**Table 1**).

Maquia et al. [70] have used ISSR markers to assess the genetic diversity in *B. boehmii* and *Burkea africana*, another typical legume tree from Miombo, across a fire gradient in NNR wherein the northeastern side is affected by annual fires and the western by bi- to triannual fires. The authors observed that the levels of genetic diversity were lower in *B. boehmii* (average genetic diversity, He = 0.1965) than in *B. africana* (He = 0.2972). Such difference was attributed to fire tolerance and adaptation, as *B. africana* is a typical fire-tolerant species, while *B. boehmii* is more sensitive to fire, particularly at young stages [74, 75]. Interestingly, in *B. boehmii* high fire frequency resulted in higher variability (i.e., He = 0.2059 in eastern *versus* He = 0.1482 in western NNR), while in the case of *B. africana*, the opposite was observed (He = 0.2977 in the west and 0.2184 in the east). Based on this observation, Maquia et al. [70] proposed that the increase in *B. boehmii* variation driven by frequent fires may be part of its evolutionary response, a phenomena called pyrodiversity-like effect [76], associated to a higher proportion of seed-derived propagation in detriment of vegetative reproduction. Overall, the study concludes that the genetic variability within and among populations as well as the estimated gene flow between populations represents a strong genetic pool of the two species in NNR, agreeing with the fact that the reserve is one of least disturbed areas of Miombo. Similar results were obtained with other species of the Fabaceae family, e.g., *Afzelia quanzensis* Welw. [73], *Astragalus rhizanthus* Royle ex Benth. [77], and *Glycyrrhiza uralensis* Fisch. ex DC [78], from conservation areas.

RAPD markers were used to characterize accessions of *P. angolensis* from Zimbabwe, Zambia, and Tanzania [79, 80]. Chisha-Kasumu and colleagues [79] characterized the genetic structure of different populations from Zimbabwe and Zambia. According to their study, the variability within each population was high (Shannon's information index, I = 81%). In Tanzania, [80] used the same strategy to analyze genetic diversity and population structure in six natural populations. In line with the results of [79], genetic diversity within populations was high (I = 77%), and in both cases, an effective gene flow was suggested. The results are within the range of those reported for other tree species [81, 82].

Villoen and collaborators [83] have used 13 allozyme markers to analyze five populations of *C. mopane* in South Africa: these included aspartate aminotransferase (AST), alcohol dehydrogenase (ADH), esterase (EST), isocitrate dehydrogenase (IDH), guanine deaminase (GDA), glucose-6-phosphate isomerase (GPI-1), leucine aminopeptidase (LAP), malate dehydrogenase (MDH), mannose-6-phosphate isomerase (MPI), peroxidase (PER), phosphoglucomutase (PGM), shikimate dehydrogenase (SKDH), and superoxide dismutase (SOD). As for *B. boehmii* [70] and *P. angolensis* [79, 80], most of the variation in *C. mopane* was observed within populations. Additionally, gene flow between populations was also effective. The results were also comparable to those obtained in the legume *Virgilia oroboides* (Berg.) [84]. The authors suggest that *C. mopane* developed an effective outcrossing mechanism that avoid inbreeding and maintain a considerable level of diversity necessary to ensure adaptation and survival under a context of ever-changing environments.

It should be highlighted that except for [70], the studies of [79, 80, 83] did not address the impact of environmental and/or anthropogenic drivers, which are determinant to understand ecosystem's dynamics. In fact, the use of molecular markers to assess tropical tree biodiversity dynamics across environmental gradients is an issue that deserves more attention. Using ISSR markers, [85] examined the effect of three different environmental gradients on the genetic diversity of the semishrub legume *Caragana microphylla* Lam. The authors observed that higher levels of genetic diversity were correlated with optimal humidity, soil fertility, and to a less extent temperature. Dai et al. [86] examined the genetic variation of marginal *Bombax ceiba* L. (silk-cotton tree) populations in China and South Asia, based on the sequences of nuclear and chloroplast genes. The results revealed extremely low levels of genetic diversity without significant differences between cultivated and natural populations. This might reflect a small number of individuals (or other founder effects) during the establishment of populations or genetic drift. Addisalem et al. [87] examined the genetic structure of *Boswellia papyrifera* (Del.) Hochst across threaten tropical dry forest (*Terminalia-Combretum*) woodlands in Ethiopia, where populations retain high levels of genetic diversity despite the diverse environmental conditions (including harsh environments, i.e., high temperatures and low precipitation) as well as progressive deforestation and degradation.

Altogether, these studies [70–87] reveal that the response of tropical trees to environmental and anthropogenic pressure is highly variable and that, in general, most of the species are resilient to extreme soil and climate conditions, being able to retain high levels of genetic diversity. This in turn highlights the relevance of integrative molecular analyses at a regional scale, to understand the mechanisms of species adaptation and evolution within the context of climate changes. A good example of the potentialities of such studies is the work developed in *Hevea brasiliensis* (Willd. ex A. Juss.) (Rubber tree) by de Souza and collaborators [88, 89], which have established a foundation of molecular markers (microsatellites and SNPs) highly valuable for breeding and conservation programs.

4. Concluding remarks

African woodlands support the livelihoods of millions of rural and urban people, providing valuable sources of wood, edible products, fibber and related products, insect products (honey and beeswax, edible insects), and medicinal plants, among others.

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Based on the available scientific information, it is our understanding that major gaps and challenges need urgently to be addressed. The development of coordinated research throughout the region to assess genetic diversity and structure as well as to define common conservation strategies, adapted to each country needs and facilities, should be prioritized. For that, effective networking between Southern African institutions and their partners from Europe and the USA seems to be the most appropriate approach. However, such interactions are not reflected in a considerable number of scientific publications. It is our conviction that collaborative work is the best way to consolidate and/or promote partnerships, resulting in mutual benefits, e.g., scientific excellence, critical thinking, team playing, access to funding, broadening information sharing to prompt innovation, translation of knowledge from "local to global," and from "global to local" contexts. The involvement of the Miombo Network for Southern Africa would be of utmost importance to incorporate key issues, such as genetic diversity and bioprospection in Miombo and also Mopane, in its research strategy plan. The inclusion of these two issues in Miombo and Mopane research will not only ensure the sustainable use and conservation of key species but also allow the establishment of modern biotechnology platforms toward the incorporation of the most valuable species into bio-based economy schemes.

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