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Status and Conditions of Stands of *Colophospermum mopane* (Mopane) in Vwaza Marsh Wildlife Reserve, Malawi †

Sopani Sichinga [1,] *, Andrew Kanzunguze [1], Leonard Moyo [2] and George Nxumayo[3]

[1]Nature-WEB Africa, Post Office Box 20536, Lilongwe, Malawi
[2]Vwaza Marsh Wildlife Reserve, Private Bag 6, Rumphi, Malawi
[3]Deprtment of National Parks and Wildlife (N), Post Office Box 498, Mzuzu, Malawi
*Correspondence: sksichinga@gmail.com; Tel.: +265 (0) 884 351 870
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Abstract: A study to assess the status and condition of *C. mopane* was carried out in Vwaza Marsh Widlife Reserve, Malawi. Ground transects and plot-based surveys were used for sampling a total of 2541 trees. Statistical analyses were carried out using SPSS version 20 for Windows (SPSS Inc. Chicago, USA). Results revealed that *C. mopane* covers 12.27% of the reserve, with no significant differences in all vegetative attributes of the species (height, DBH, basal area, and density) except for stocking density (P>0.036). In terms of damage, results revealed low (37%) elephant damage. Continuous monitoring of *C. mopane* populations in relation to different forms of damage is encouraged, alongside further research into the ecological dynamics of biodiversity components about the reserve with mopane woodlands.

Keywords: *Colophospermum mopane*; Elephant; Damage; Conservation

1. Introduction

Colophospermum mopane (Mopane) is one of the principle trees of southern tropical Africa which tends to exist as monospecific stands in woodland form, commonly called mopane woodlands [1-3]**.** Within this range, mopane woodlands have been well reported to play highly significant socioeconomic and ecological roles [2-4]. This includes in Malawi, where such importance was reported as contributing to its significant decline outside of protected areas in the late 1900s within the country [5]**,** thus warranting their protection by law [6]. The most recent assessment by the International Union for the Conservation of Nature (IUCN) confirms its populations are still considered in decline as a result of overexploitation, although site-specific information on local population sizes and trends is scant [7].

Vwaza Marsh Wildlife Reserve (VMWR) (Figure 1) is one of the protected areas where mopane occurs [8]. In this reserve, mopane significantly adds to biodiversity in addition to being an important wildlife habitat [8]. Despite this, an information deficit has remained prominent regarding the current status and condition of mopane woodlands in the protected area even though accelerated degradation of the woodlands due to wildlife damage and fires has been increasingly reported in other protected areas [9-11]. Therefore, this study aimed at providing information on the status and condition vis-à-vis elephant damage. Such information is deemed essential for development of effective and sustainable management strategies for both mopane and the associated biodiversity across its range.

2. Methods

Study Area: The reserve lies in northwest Malawi along the international border with Zambia (Figure 1), spreading over 986 km^2 with varying altitude from1000m to 1660m [8]**.** Mean annual rainfall is about 800-1100 mm across the reserve, falling from November to April [12]**.** A more detailed description of reserve is given by [13].

Figure 1. Map of Vwaza Marsh Wildlife Reserve, Malawi.

Sampling Procedure: All areas with mopane were first mapped using ground transects and a GPS device then categorized into 3 sections (i.e., A = Alluvial plains/Mopane association; B = Alluvial plains/Deciduous-thicket mopane association; and C = Alluvial plains/Pediment alluvial) based on landscape classification by [14]**.** A total of 109 rectangular plots (20m x 30m each) were randomly laid within all sections (A=39, B=36, C=34).

Data Collection: Data was collected between August and December 2020. Using standard forest inventory techniques [15], data on tree/shrub height, basal circumference, number of stems per plant, number of saplings/regenerants, number of dead trees and plant damage was recorded. Data on associated species were recorded with the aid of visual field guides [1, 16] and verified on flora of Malawi database - https://www.malawiflora.com/ .

Elephant damage assessment: Damage was defined as any form of vegetation utilization by elephants [10]. In this study this included breaking of branches and stems, uprooting, pushing over and scarring (bark striping) of *C. mopane*. Eye observations were used to determine damage form and intensity [17, 18], and score overall elephant damage according to a 4-point scale (0=no damage, 1=slight damage, 2=moderate damge, 3=severe damage. Fire and human induced damage was also noted and recorded as 'other damage'.

Data Analysis: The collected data was entered, cleaned and organized using Microsoft Office Excel 2010. Spatial mapping was done using Quantum GIS (QGIS) map tools, and statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS) version 20 for Windows (SPSS Inc, Chicago, USA). A One-way analysis of variance (ANOVA) was performed to test for significant differences in age/size, elephant damage between sections. A post hoc Tukey Honestly Significant Difference (Tukey HSD) test was then carried out to separate significantly different means.

3. Results and Discussion

3.1. Distribution of C. mopane in VMWR.

C. mopane in Vwaza occurs in low-laying alluvial plains (within altitudinal range of 1000-1150m), covering an area of approxmately 121 km² mostly in the central and south-central areas of the reserve (Figure 3). These are areas characterized by moderately deep to deep loamy and clay soils including grey clays described by [14], and the distribution appears to strongly follow soil type. The ground cover within mopane areas is generally very light, with large open glades of grassland, comprising of Loudetia simplex and Setaria species wih very little herbecious cover.

Although not dipicted in recent distribution range map by [19], this distribution of mopane in Vwaza Marsh wildlife Reserve is at its most northerly occurrence in Africa, and extends into Zambia to the south-west adjoining that of Luangwa Valley (Zambia).

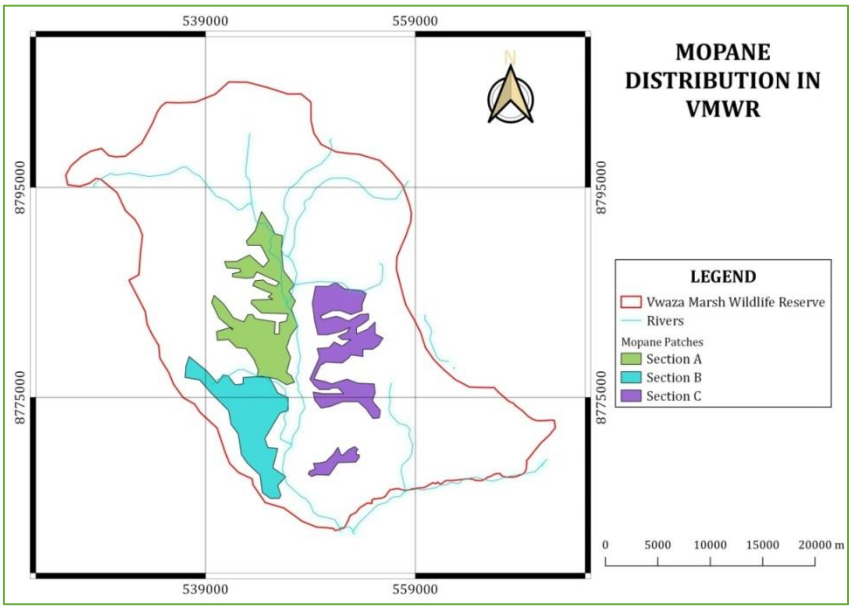

Figure 2. Distribution of mopane in VMWR.

3.2. Size/age structure of C. mopane in VMWR.

A total of 2541 C. mopane (both trees & shrubs) was assessed in 109 random sampling plots, across all the three sections of mopane (Table 1).

Table 1. Assessed Mopane trees.

Section	Approx. Area (km²)	No. of Plots (20m×30m)	No. of *C. mopane*		Total trees
			Trees (>2 m)	**Shrubs** (≤2 m)	
A	49	39	809	74	883
B	39	36	841	75	916
C	33	34	701	41	742
Total	**131**	**109**	**2351**	**190**	**2541**

In terms of size, C, mopane trees were almost equally represented in all sections with evenely distributed mean proportions (7.0-7.6%) across DBH classes, except for the larger girth size which had the least proportion (Figure 3). This means that more than one size class of mopane predominates in Vwaza demostrating a balance of age/size classes.

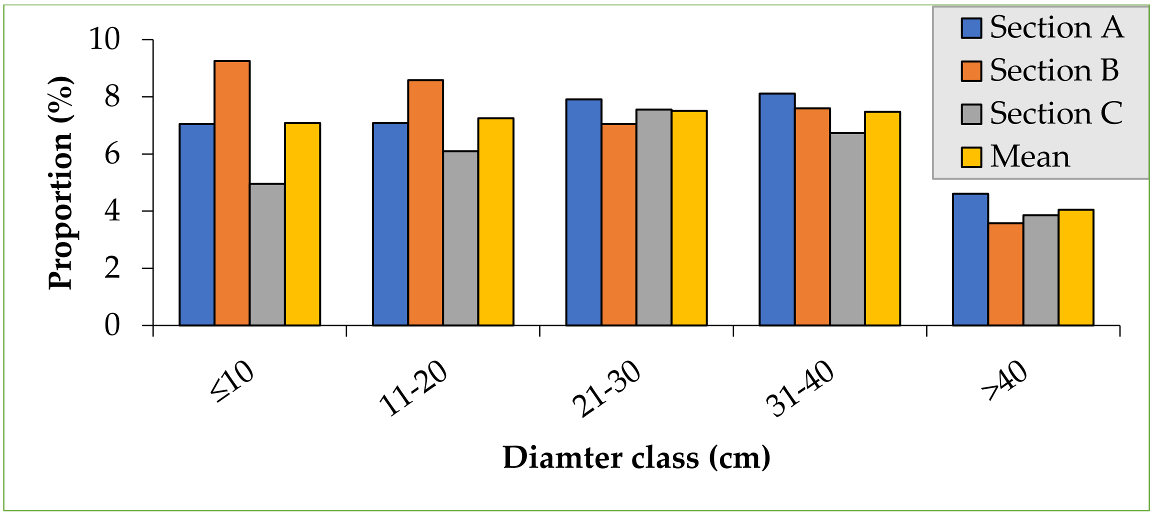

Figure 3. Distribution by DBH Classes.

Mean dominant height was in the range of 12-13m with with basal area in between 22 and 24 m^2/ha (Table 2). All vegetative attributes of C. mopane in VMWR did not significantly differ across sections except for stocking (P=0.036), which was highest in section B (Table 2).

Table 2. Vegetation attributes (mean ± standard error) of *C. mopane* in VMWR.

Variable	Section A	Section B	Section C	P-value
Dominant height (m)	12.54(±0.19)	12.41(±0.16)	12.35(±0.16)	0.720
Basal area (m^2/ha)	23.58(±1.42)	23.04(±1.28)	22.08(±1.06)	0.935
Stocking density (m^2/ha)	377(±12)^b	424(±23)^a	364(±12)^b	0.036
Sapling [1] density (m^2/ha)	153(±15)	196(±78)	103(±16)	0.384
Density of dead trees (m^2/ha)	26.54(±5.08)	23.64(±4.80)	18.21(±4.13)	0.457

NB – Values (mean ± standard error) with different letter-superscripts within stocking density variable row denote significant differences. [1] Sapling is defined as a seedling that has survived the dry season and enters the second growing season as a sapling [23].

In the field, the common phenomenon of mopane occurring in several physiognomic forms ranging from short mopane, medium mopane to tall mopane, with an even-sized appearance of stands was evident (Figure 4). Although it is commonly reported that even-sized appearance generally demonstrates episodic or cohort recruitment across mopane woodlands [2, 20], this was not supported in this study as results showed no evidence of that as more than one age/size class predominates. Further scientific studies are therefore required to elucidate the concept of episodic recruitment in mopane woodlands (i.e. whether even-sized stands of mopane are even-aged, and whether recruitment is episodic).

In terms of physiogmomy, edaphic factors are reported to largely control mopane physiognomy, i.e. shrub versus tall tree forms [21].

Figure 4. Physignomic forms of *C. mopane* in VMWR; (A) shrub mopane, (B) medium mopane, and (C) tall mopane.

Saplings (0.5 m high) were also common though patchily distributed, indicating good seed production and germination/regeneration. This is most likely due to high proportion of large mopane trees (>4m) as there is unlikely a seed supply limitation when trees exceed 4m in height [22]. In addition, a high incidence (over 60%) of coppicing of damaged mopane trees (especially those with broken stems) and saplings was also noted and mortality was low. This also is an indicative of good natural regeneration after disturbances which include periodic drought, frost, fires and vertebrate damage.

Other associated species; - A total of 31 species associated with mopane were recorded and the most common (occurred in >80% of total plots) included; *Albizia harveyi*, *Canthium frangula, Cissus gracilis, Combretum apiculatum*, *Commiphora caerulea, Commiphora mollis, Dalbergia melanoxylon*, *Dichrostachys cinerea, Diplorhynchus condylocarpon*, *Grewia bicolor, Grewia monticola, Lannea schimperi*, *Rhus longipes, Senegalia nigrescens, Vachellia nilotica, Xerophyta retinervis, Ximenia americana, and Ziziphus mucronata*. Consequently, mopane (the most dominant species) and the other species listed above could be treated as key species for classifying the vegetation of mopane woodland in Vwaza.

3.2. Elephant damage

37% of the total mopane trees assessed (n=2541) were damaged by elephants, 2% had other forms of damage, whereas 61% were not damaged. There was no significant differences in the proportion of damaged trees across mopane sections of VMWR (P=0.340) and the damage was almost uniform with more trees being slightly damaged.

Plants of less than 30 cm girth size were the most affected (Figure 5), and the damage distribution was patchy with few localized dwarf *C. mopane* (1.5 – 2m). This supports the notion that the form of elephant damage and the level of plant's vulnerability to elephants depend on the size of the tree [11]. Furthermore, as dwarf mopane is a result of continuous/ or excessive browsing especially by elephants [2], their rarity also adds credence to the generally low level of elephant damage to mopane woodlands in Vwaza.

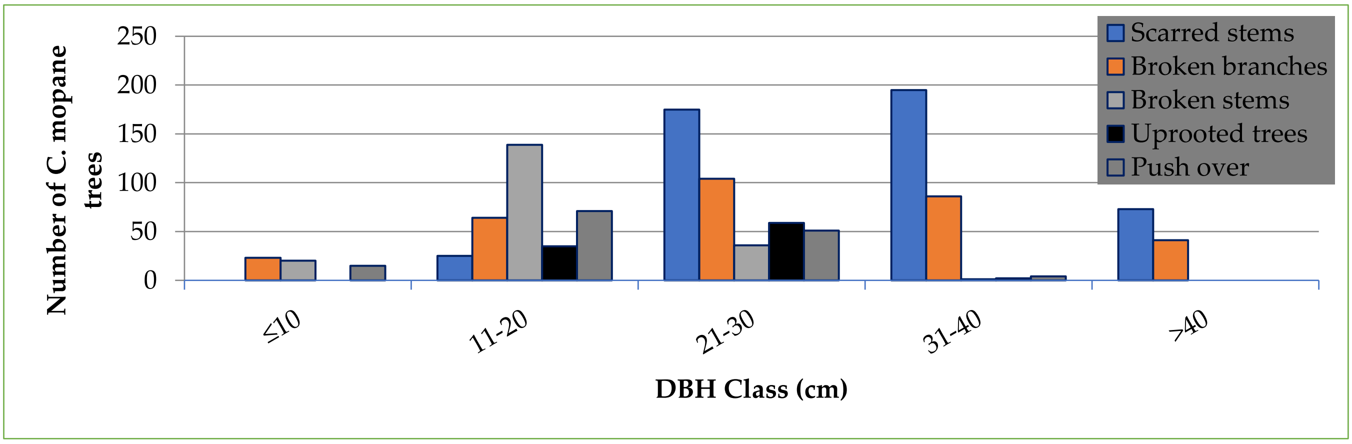

Figure 5. Elephant damage to *C. mopane* in VMWR.

The low elephant damage could be ascribed to low elephant density which is currently estimated at no more than 0.25/km^2 as compared to the reserve's desired density of approximately 0.8(±0.1)/km^2 [11]**.** However**,** while it is likely that relationship between elephant density and damage is exponential [24], the size of the elephant range, the patterns of elephant distribution, distribution of permanent surface water, floristic and physiognomic composition of the vegetation and elephant occupancy of different habitats will all influence the pattern and scale of elephant damage [25].

For instance, seasonal site elephant occupancy appeared to have also contributed to low elephant damage in Vwaza as elephants have been observed to rarely visit/ or occupy mopane woodlands during the dry season [14, personal observation], the time elephants are reported to heavily utilize/damage mopane [26]. This was confirmed by the absence of fresh damage during the dry season of the study period.

Reasons as to why elephants rarely visit mopane woodland in Vwaza are not yet known. However, scarcity of permanent surface water in mopane sites during the dry season in Vwaza could be one of the reasons as surface surface water availability has a strong influence on elephant movements [27]**.** However, further investigations into elephant seasonal-site occupancy/movements within the reserve would explain this better.

4. Conclusion and Recommendations

The study reveals that mopane wooodlands in Malawi's VMWR occupy approximately 12.27% (121 km^2) of the total reserves area. In its current local range, the woodlands occur in physiognomic forms, with almost even distribution in height and diameter classes across *C. mopane* clusters. *C. mopane* saplings are common in the reserve, as is the incidence of coppicing and presence of large (>4m height) seed trees. The extent and intensity of elephants damage is generally low (37%), with scarring and broken branches the most common. Other forms of damage were as low as 2%.

Continuous monitoring of *C. mopane* populations is strongly encouraged to keep in check the damage levels arising from elephants, fires and humans. However, further investigation into the ecological dynamics and relationships of mopane with fauna in VMWR are recommended.

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