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ELEPHANT UTILIZATION PATTERNS AND CHANGE IN STRUCTURE OF MOPANE WOODLAND IN THE LUANGWA VALLEY, ZAMBIA

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Abstract
The objective of the study was to measure and compare vegetation structure and elephant utilisation patterns between woodlands of South Luangwa National Park with short mopane and Lupande Game Management Area with tall mopane. In a field survey conducted, 328 coppiced mopane plants were measured from 10 plots in the national park and 70 tall mopane plants from 10 plots in the game management area for difference in woodland size, height and crown size, and were also measured for branch breaking, main stem breaking, stem twisting, bark peeling and tusk marking. Measurements of woodland structure and patterns of elephant utilisation and compared using a t-test for equality of means. The cut off point for statistical significance was set at 5%. Analyses showed a plant height of 12.76 (SD 4.92) m in tall mopane compared to that of 2.71 (SD 0.85) m ($p<0.001$) in dwarf mopane ($p<0.001$). The diameter at breast height (DBH) of coppiced mopane was 6.84 (SD 2.48) cm whereas the DBH of the tall mopane was 36.29 (SD 14.74) cm ($p<0.001$). More coppiced than tall mopane trees were utilized by elephants (branch breaking: 100% vs 12%, $p<0.001$; main stem breaking: 38% vs 1%, $p<0.001$; stem twisting: 58% vs 4%, $p<0.001$; bark peeling: 94% vs 30%, $p<0.001$ and tusk marking: 13% vs 0%, $p=0.003$ respectively. Heavy utilisation contributed to change of woodland structure. Thus, woodland vegetation differences increased elephant use of coppiced mopane as compared to tall mopane woodland.

Key Words: *Colophospermum mopane, Elephant utilization of mopane, Eastern Zambia*

Introduction

African elephants (*Loxodonta africana*) graze and browse a wide range of plants and habitats. Savanna areas of southern Africa with high elephant numbers experience over-utilization of woodlands (Ben-Shahar, 1996; 1998). Continuous herbivory of preferred plant species can trap trees into forms exploitable by elephants, hindering recruitment to taller classes (Mapaure and Campbell, 2002; Simbarashe and Farai, 2015). Elephant utilisation of vegetation can change woodland into grassland (Styles and Skinner, 2000; Mapaure and Campbell, 2002; Gandiwa *et al.,* 2011). Mopane (*Colophospermum mopane*) woodland utilisation by elephants is by main stem breaking, branch breaking and bark peeling of plants.

Colophospermum mopane is a staple food plant for African elephants and where it is established, the species is dominant with almost monotypic woodland stand (Ben-Shahar, 1993). In different areas *C. mopane* occurs in dwarf forms (coppiced mopane) and tall tree forms (Phiri, 1989; Milambo and Mapaure, 2006). Coppiced mopane growth form has been associated with continuous herbivory (Phiri, 1989; Smallie and Connor, 2000; Styles and Skinner, 2000). Continuous herbivory by elephants on woody plants is known to limit woody vegetation growth (Styles and Skinner, 2000; Gandiwa *et al*., 2011; Ben-Shahar, 1998; Smalle and Connor, 2000; Mapaure and Mhlanga, 2000; Mukwashi *et al.*, 2012; Gandiwa *et al.*, 2013; Simbarashe and Farai, 2015).

Numerous studies have been done on impact of elephant herbivory on woody vegetation (Van Wyk and Fairall, 1969; Mapure and Campbell, 2002; Gandiwa *et al.,* 2011; Poilecot and Gaidet, 2011; Simbarashe and Farai, 2015) as well as taxonomic studies of Luangwa Valley vegetation (Astle *et al.*, 1997; Smith, 1997; Phiri, 1989; Phiri, 1994) but studies on woody structures of coppiced and tall *C. mopane* growth forms and elephant utilisation patterns of *C. mopane* in the Luangwa Valley in eastern Zambia have not been done.

In the Luangwa Valley, continuous and excessive browsing of coppiced *C. mopane* woodland as opposed to tall *C. mopane* woodland has been observed (Phiri, 1989). In addition, *C. mopane* woodland structure in Chichele area of South Luangwa National Park (SLNP) is coppiced while *C. mopane* woodland in Kakumbi area of Lupande Game Management Area (LGMA) is tall, large and intact. Utilisation through herbivory pressure appears to have contributed to the alteration of *C. mopane* woodland structure of which elephant utilisation could be the main factor in the development of coppiced mopane woodland (Styles and Skinner, 2000). *C. mopane* woodland forms part of the extensive savanna of low inland valley of the Luangwa Valley in eastern Zambia. The main objective of this study was to compare vegetation structure and elephant utilisation patterns between coppiced mopane and tall mopane in the Luangwa Valley, in particular SLNP and LGMA.

Materials and Methods

Study Area

The study sites were Chichele in SLNP and Kakumbi in LGMA in the Luangwa Valley, eastern Zambia (Figure 1). The Luangwa Valley is a trough lying below the MuchingaEscarpment to the north and forms the Luangwa River catchment area. It stretches between 9° 35′ S to 15° 41′ S and 28° 21′ E to 33° 44′ E (Phiri, 1989). The Valley covers an area 40,000 km^2 in extent, approximately 700 km in length and 90 km at its widest point, stretching through Muchinga escarpment hill floor, covering part of Eastern, Central and Lusaka Provinces of Zambia (Smith, 1977; Phiri, 1989; Phiri, 1994).

SLNP is situated in the Luangwa Valley and covers an area of about 9050 km^2 in extent (Smith 1977). The national park lies between 12° 17′ - 13° 45′ S and 31° 00′- 32° 08′ E of which it is integral to the Great Rift Valley where the rift divides into the eastern arm encompassing Lake Malawi and the western arm forms the Luangwa Valley stretching north for some 700 km (Smith 1977; Phiri 1994). LGMA was established to buffer SLNP to the east. LGMA is 4,840 km^2 in size and lies between 13° 30′ S and 14° 45′ E at 350 m to 640 m above sea level (Phiri, 1989). The Muchinga Escarpment to the north of the national park rises to 1,200 m above sea level (Smith, 1977).

The valley has three distinct seasons namely: hot rainy season (late November to April); cool-dry season (May-August); and a hot dry season (September to early November). The average daily maximum temperature ranges from 32 to 36ºC. The average minimum temperatures are about 15° C during months of June and July. The average annual rainfall ranges from 832 to 889 mm, although rainfall episodes of up to 1000 mm have been recorded in some parts of the valley (Phiri, 1994).

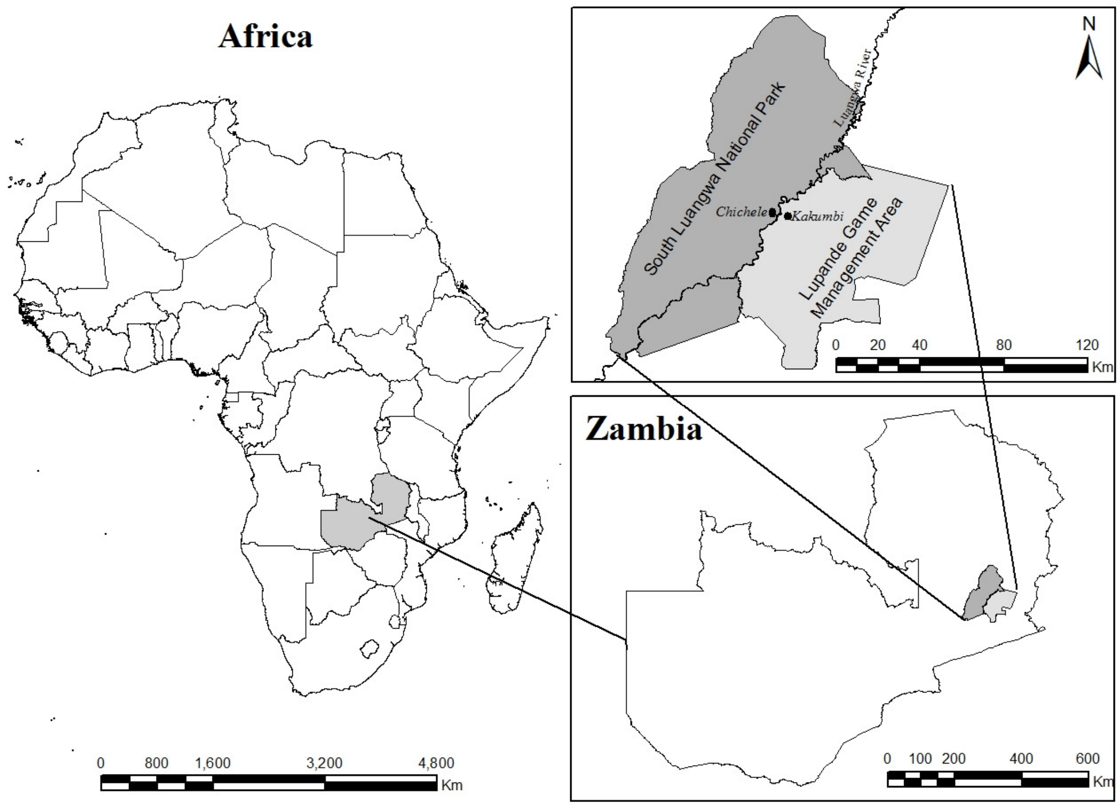

Fig. 1: Location of the study area in *Colophospermum mopane*-dominated vegetation type in the Luangwa Valley in eastern Zambia.

Data Collection

Before embarking on the study, a reconnaissance survey was done by traversing the study area with a combination of automobile where tourist roads existed and on foot to have a general idea of the distribution belts of pure stands of coppiced and tall *C. mopane* woodland and to identify areas preferred by elephants and evidence of utilisation by elephants. Two by five-hectare blocks of monotypic stands of coppiced and tall mopane woodland - UTM: 0359630 and 8544808 at 512 m elevation in SLNP and

UTM: 0366665 and 8543272 at 546 m elevation in LGMA were marked. The two plots were separated by 6.21 km linear distance and were delineated using loop roads and rivers. The plot in SLNP where Chichele Site was marked was bounded by loop roads to the north, east and west and the Luangwa River to the south. The block in LGMA where Kakumbi Site was located was defined by loop roads to the north and west and an annual stream to the east.

Ten plots, each measuring 20 x 20 m, were marked in each five-hectare block on Chichele Site of SLNP and on Kakumbi Site of LGMA following Mapaure and Mhlanga's (2000) method. Plots were marked 10 m away from the nearest road. A GPS (Garmin GPS MAP 78 series) was used to locate positions and elevations of the sampled plots.

The measurements of *C. mopane* woodland structure and utilisation patterns were conducted in SLNP and LGMA. The two sites were separated by the Luangwa River of which Chichele site was located north of the river while Kakumbi site was in the south (Figure 1). The Luangwa River is not a physical barrier to elephant movements from SLNP into LGMA and back. In addition, human settlements in LGMA do not appear to prevent elephants from accessing the tall mopane woodland in LGMA. During this study, herds of elephants were seen moving from SLNP around 16:00 hours to LGMA and back to SLNP around 09:00 hours the following day.

Data on woody structure and elephant utilisation of coppiced and tall *C. mopane* on Chichele site in SLNP and on Kakumbi Site in LGMA, respectively were collected in April 2016, at a time of the year when there was improved visibility and accessible loop roads. Good visibility was important during this study since the study area hosts dangerous animals including lion, elephant, buffalo, hippo, leopard and crocodile. In each plot the following vegetation variables were recorded for vegetation structure (Mapaure and Mhlanga, 2000): vegetation structure (diameter at breast height, height and crown size) and elephant utilisation (main stem breaking, branch breaking, bark peeling and tusk marking). *C. mopane* plants located on plot margins were considered to be inside the plot if half of the root system was inside the plot (Walker, 1976). Multi-stemmed plants with more than half of their base inside the plot were recorded as e inside the plot (Kent, 2011).

Measuring Diameter at Breast Height

To determine the size of the tree, diameter at breast height was measured from the ground using a measuring tape placed around the tree bole. In the case of multi-stemmed trees, the circumferences of all stems were measured and the average circumference was recorded (Simbarashe and Farai, 2015).

Measuring Tree Height

In coppiced *C. mopane* woodland plant height was measured using a 6 m calibrated height measuring gauge. The gauge was placed against the tree in a way that allowed reading the height values, including when the gauge was raised against a tree. In tall *C. mopane* woodland where trees were so tall that the 6 m calibrated height measuring gauge could not be used, an Abney Level was used to read the angle (Tan D) at a constant distance of 30 m away from the tree for height calculations.

Measurement of Crown Diameter

Two crown diameters (four radii) were estimated using a measuring tape. The directions of the first diameter and the second were selected at right angles – north to south and east to west with the mean diameter calculated thereafter.

Measurement of Elephant Utilisation

Elephant utilisation was defined as any form of *C. mopane* woodland use of which main stem breaking, branch breaking, bark peeling and tusk marking were the parameters measured in this study. Utilisation was estimated through eye observations (Mapaure and Mhlanga, 2000).

Data Analysis

IBM SPSS statistics Release 20.0 was used in the analysis. Means were compared using t-test for independent samples, while proportions were compared using the Yates corrected Chi-squared test. The level of statistical significance was set at 5%.

Results

A total of 398 individual woody plants were recorded from 20 plots measuring 20 x 20 m (328 individual coppiced mopane plants were recorded from 10 plots in SLNP and 70 tall mopane plants from 10 plots in LGMA). In the Luangwa Valley, tall *C. mopane* had an average height of 12.76 (SD 4.92) m compared with coppiced mopane with average height of 2.71 (SD 0.85) m; p<0.001. The average DBH of coppiced mopane trees was 6.84 (SD 2.48) cm compared to the average DBH of tall mopane of 36.29 (SD 14.74) cm; p<0.001. The average crown diameter of tall Mopane plants was 9.20 (SD 3.74) m compared to coppiced mopane with the average crown size of 1.7 (SD 0.78) m; p<0.001. From five-hectare plots, coppiced mopane plant density was 66 trees per hectare while tall mopane occurs at 14 trees per hectare. The difference was statistically significance (p<0.001).

Table 1 shows elephant utilization patterns of coppiced and tall mopane. Overall, elephant significantly utilized more coppiced than tall mopane. Branch breaking (100%) and bark peeling (94%) were the common forms of utilization of coppiced mopane, while the most common form of utilizing tall mopane was bark peeling (30%).

Table 1: Elephant utilisation patterns of coppiced and tall *Colophospermum mopane* woodland trees

Variable	Coppiced mopane	Tall mopane	p value
	Total = 328 trees	Total = 70 trees	
	n (%)	n (%)	
Branch breaking	328 (100)	8 (12)	<0.001
Main stem breaking	124 (38)	1 (1)	<0.001
Stem twisting	190 (58)	3 (4)	<0.001
Bark peeling	308 (94)	21 (30)	<0.001
Tusk marking	42 (13)	0 (0)	<0.003

Discussion

Coppiced mopane woodland on Chichele Site of SLNP was heavily utilised by African elephants. Mopane in this area appeared to be the preferred food plant by elephants. There appeared to be continuous utilization of coppiced mopane woodland attributed to elephants. Herbivory by other species such as buffaloes were not significant in the Chichele area. The African buffalo is a grazer that feeds on grasses and herbs.

Although it can occasionally browse on leaves the species does not push over trees, break stems or branches while feeding. Browsing by giraffe and kudu is also not by main stem breaking, branch breaking, bark peeling or branch twisting, they forage on terminal shoots and leaves. The utilizable coppiced mopane plant shoots were not more than 7 cm in size and were less than 3 m tall. This attests to how susceptible plants in this class size are to elephant utilization. Branch breaking (100%), bark peeling (94%) and stem twisting (58%) were the most common form of utilization (Table 1) in coppiced mopane woodland on Chichele Site due to easy accessibility by elephants of small branches and terminal shoots as earlier observed by Mapaure and Mhlanga (2000).

Continuous herbivory appears to be maintaining coppiced mopane woodland variant at average height of 2.7 m. Maintaining plant height at 2.7 m permits easy access to feed. Elephants break branches, trunks, peel barks and twist trunks to forage since terminal shoots of coppiced mopane plants are easily accessible. This supported research on patterns of elephant utilization of *C. mopane* noted on selected islands in Lake Kariba (Mapaure and Mhlanga, 2000). During this study, coppiced mopane appeared to reproduce vegetatively from main stems pushed over or broken by elepants and occured at a density of 66 trees per hectare compared to tall mopane with a density of 14 trees per hectare. It appeared that when the coppiced mopane plant part for photosynthesis was removed, more water and nutrients were made available for the remaining photosynthetic plant part, thereby increasing its shoot growth performance (Alados *et al*., 1997).

Herbivory in tall mopane vegetation was mainly by bark peeling (30%) and branch breaking (12%). All records of bark peeling and branch breaking in tall mopane plants were 2 years old or more since they appeared gray in colour during this survey. It is not clear why there was absence of continuous herbivory in tall mopane of LGMA by elephants when there existed trees of sizes that could be pushed over for browse.

In this study, herbivory of *C. mopane* was less intense during months of December to February presumably due to increased protein content in green grass during the growing season (Osborn, 2004) and alternative food sources of feed in LGMA but these phenomena require further investigation. Elephants were observed to frequently move from SLNP to LGMA and back to SLNP.

Impacts of elephants and fire have also been attributed to change of woodland to grassland (Dublin *et al*., 1990). Man can affect the structure since fires introduced by man accidentally or intentionally, especially during late dry season can impede regeneration and could kill mature trees (Trapnell 1959). Both SLNP and LGMA have had no fire management plans and fire in the two protected areas was started by poachers, fishermen and fish mongers as well as fire wood collectors and those collecting grass for pole and mud grass thatched houses and kraals. Change to coppiced mopane woodland growth form can not be attributed to fire since the same uncontroled fires affect tall mopane woodland of LGMA as well. The differences in woody vegetation structure across the two land use systems appears to indicate that the role of herbivory pressure is a factor in influencing woody structure and habitat.

Structural changes of coppiced mopane woodland of SLNP and tall mopane woodland of LGMA suggest differences in elephant utilisation patterns of the two mopane woodlands at habitat scale. However, factors including topography, edaphic and moisture variations require investigation. Significant differences in diameter at breast height, height and crown size between coppiced mopane woodland of SLNP and tall mopane woodland of LGMA highlighted variances in intensity of herbivory in influencing the recorded woody plant structural changes. Woody vegetation structural variability is important for management and monitoring since it influences forage quality and nutrient availability (Muboko *et al*., 2013). This study revealed that mopane woodland structures and utilization in SLNP and LGMA were significantly different. Therefore, long-term monitoring of mopane woodland is necessary to determine possible changes over time and put in place appropriate management practices to conserve the habitat and biodiversity components. Further studies are recommended to determine other factors influencing status of mopane woodland structure and elephant utilization patterns.

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