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Vanishing Multipurpose Indigenous Trees in Chobe and Kasane Forest Reserves of Botswana

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Abstract The continued threat to the forest and land resources has been acknowledged in many parts of Botswana. In 2003, a field study was carried out to assess the structure and composition of Chobe and Kasane Forest Reserves. In both forest reserves ten plots (25 m x 25 m) were established at 100 m inter-plot spacing along a transect of 1 km. The information recorded from each sample plot includes tree and shrub species name (species identification), diameter at breast height (dbh) and height of all trees with at least 3-cm and indicators of biotic disturbances/human and animal disturbances (stems cut, dead and wounded trees, grazing/browsing, burnt areas). The forest structure was described by species diameter class distribution, basal area and species diversity index (Shannon's Index) while the number of different species described the forest composition. Chobe Forest Reserve showed the highest number of total stems per hectare/tree density (2048 stems/ha) as compared with Kasane Forest Reserve (544 stems/ha) with most of the trees being found in the 21-30 cm (672-stem ha^{-1}) and 41-50 cm (144-stem ha^{-1}) diameter classes respectively. Chobe showed significantly ($P = 0.05$) higher tree basal area (146.20 m^2 ha^{-1}) and species diversity (H: 7.7281) as compared with Kasane (i.e. basal area: 41.93 m^2 ha^{-1} and H: 6.7038). The average tree mortality rate in Chobe was 60% with *Pterocarpus angolensis* showing the highest proportion (21% tree losses). Out of the 40% living trees, however, fire or elephants either wounded 16.3%. Kasane showed higher proportion of wounded living trees (26.5%) as compared to Chobe. It is concluded that *Pterocarpus angolensis* (Mukwa), *Baikiaea plurijuga* (Mukusi), *Combretum zeyheri*, *Combretum gratissimus, Terminalia sericea* (Mogonono), *Burkea africana (*Monalo /Musheshe) and *Lonchocarpus capassa* dominate the vegetation of Chobe and Kasane Forest Reserves. Chobe Forest Reserve, however, is high diverse in terms of species and more stable as compared with Kasane Forest Reserve. Abundance of young trees in Chobe Forest Reserve provides an indication that regeneration in the forest reserve was taking place and also that the plant population structure is stable. Human activities (eg. illegal and selective harvesting of valuable species) and plant damage by other biotic factors are responsible for the observed losses of valuable indigenous species such as *Pterocarpus angolensis*, increased land degradation and suppressions of natural regenerations. To reduce the risk of damage from future biotic and abiotic disturbances on Botswana's forest resources, therefore, there is a need for harmonizing societal needs, resource potential and institutions guiding resource use, effective and sustainable forest management, forest conservation and enhancement of forest carbon stocks. More detailed studies, however, are required to determine the species richness (relative density), abundance (relative dominance), importance value index, diversity, volume distribution and canopy cover of all Botswana forests. Qualitative and quantitative data on the destructive impacts of biotic and abiotic disturbances are also urgently needed. Fire management plan and policy also need to be developed.

Keywords Tree diversity, Diameter distribution, Multipurpose tree/shrub species, Biotic disturbances, Botswana

1. Introduction

Natural forests and woodlands play a vital role in the existence and survival of most of the living organisms in Botswana and other parts of the world. They are storehouses for a diversity of plants and animals, provide water, food, fodder, forage, fuel wood, mulch, building materials and medicines and fulfill both cultural and spiritual needs [1-3]. They also enhance ecotourism, absorb carbon dioxide (CO_2) and supply the much-required oxygen (O_2) for breathing [4, 1]. Biotic disturbances (i.e. anthropogenic activities, fire, insect pests and diseases, wildlife browsing, grazing and physical damage by animals) and abiotic disturbances /disturbances caused by non-living factors (e.g. air pollution, wind, ice, snow, floods, landslides, tropical storms, drought

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and tsunami) have major positive and negative impacts on forest ecosystems [5, 6].

They influence forest structure, composition and functioning and can be important for maintaining biological diversity and facilitating regeneration. When disturbances exceed their normal range of variation, however, the impacts on forests can be extreme affecting entire landscapes, causing large-scale tree mortality and complete destruction of undergrowth and soils [6].

Land use for settlement and infrastructure development, arable and pastoral agriculture, unsustainable fuel wood harvesting and logging operations, cutting of live wood resources for building poles and fencing materials for kraals and homes, increasing populations of both domesticated and wild animals and frequent bush fires [7-17] are among the major anthropogenic activities and biotic disturbances which play a big role in the dynamics and depletion of Botswana's forest resources. Harmonizing societal needs, resource potential and institutions guiding resource use, effective and sustainable forest management, forest conservation and enhancement of forest carbon stocks may reduce the risk of damage from future biotic and abiotic disturbances on Botswana's forests. Before sustainable management strategies can be instituted to any forest, however, it is essential to know and understand the structure and composition of forest [18]. While considerable information exist on characteristics of Botswana flora / vegetation types (e.g. mopane woodland, miombo woodland, teak forest, moist evergreen forest, deciduous woodlands, etc.) [15, 19], no information is readily available on the structure and composition of Chobe and Kasane Forest Reserves and other forests of Botswana. Forest structure and species composition is important in management of multiple forest resource, wildlife, aesthetics, hydrologic recovery, range of forage conditions and as bases for projecting changes in vegetation over time [18]. It is also important for regeneration, growth, mortality, understory development and spread of disturbances [20]. Structure has been defined as the distribution of trees by diameter classes [21] or the distribution of species and tree sizes in a forest area [22]. Composition, on the other hand, is the assemblage of plant species that characterize the vegetation [23]. The most common measure of composition is richness (the number of different species) and abundance (the number of individuals per species found in specified area) [18]. The objective of this study was, therefore, to assess the structure (i.e. species diameter class distribution, basal area and species diversity index/Shannon's Index) and species composition of Chobe and Kasane Forest Reserves.

2. Materials and Methods

2.1. Study Site Description

During the July 2003 period a field study following a systematic sampling method was conducted in the Chobe and Kasane Forest Reserves which are located in Chobe District. Chobe District (longitude: 24^{o}E and 26^{o}; latitude: 17^{o}S and 19^{o}S; altitude: 930-1000 m; annual rainfall: 500-600 mm) is located in the northern part of Botswana where the four African nations of Botswana, Namibia, Zambia and Zimbabwe converge [24, 13, 15]. The district covers a total land area of 22559 km^2 of which 11700 km^2 (about 52%) and 17831 km^2 (79.0%) are the areas covered by both Chobe National Park alone and Chobe National Park and all the six forest reserves respectively [13, 15]. The Chobe Forest Reserve is located in Chobe National Park while the Kasane Forest Reserve which acts as a buffer zone for the Chobe National Park is bounded to the north by the Kasane town and Kazungula village, Zimbabwe to the east and Chobe National Park to the west [15].

2.2. Data Collection Methods and Analysis

Using a compass and measuring tape one transect of 1 km long was established at 50 m from the fireguard in Kachikau Village, Chobe District. Another 1 km transect was established at 50 m from the Kasane Forest Extension fire line. In both forest reserves ten plots (25 m x 25 m) separated with 100 m (inter-plots spacing) along the transect were marked. In each plot all the trees or individuals with at least 3 cm diameter at breast height (dbh) were identified and their dbh (cm) and height (m) measured using both a Caliper/tape measure and Suunto Clinometer respectively. Indicators of biotic disturbances / human and animal disturbances (stems cut, dead and wounded trees, grazing/browsing, burnt areas) were also recorded. Data on dead and live trees was used to calculate the tree mortality rate in both forests.

Tree data were grouped into 8 diameter classes (3-5, 6-10, 11-15, 16-20, 21-30, 31-40, 41-50 and > 50 cm. These gave the frequency of trees in each diameter class. The frequency distribution table was then used to draw bar chart graphs. The stems per hectare for all diameter classes in each forest reserve was summed to give tree density in the studied forests.

The basal area of each tree in each plot was calculated using the following formula:

$$\text{(i) Basal area (cm}^2\text{)} = (\text{diameter}/2)^2 \times \pi. \quad (1)$$

The basal area for all the trees in each plot was summed and divided by the size of the plot to give basal area per hectare (m^2 ha^{-1})

The tree species diversity was determined using the Shannon's formula as follows:

$$\text{(ii)} \quad H = -\sum pi \ln pi \quad (2)$$

Where:

H represents the Shannon Index; pi: the proportion of the total contributed by each species and lnpi: pi logarithm to the base e.

$$\text{(iii) The relative basal area decrease (\%)} = (Ba_K - Ba_C)/Ba_C \times 100 \quad (3)$$

Where:

Ba_K represents basal area in Kasane Forest Reserve and Ba_C: basal area in Chobe Forest Reserve.

A paired sample t-test was carried out to compare both Chobe and Kasane Forest Reserves in terms of tree species diversity and basal area.

3. Results and Discussions

3.1. Composition of Chobe and Kasane Forest Reserves

Pterocarpus angolensis (Mukwa), Baikiaea plurijuga (Mukusi), Combretum zeyheri, Combretum gratissimus, Terminalia sericea (Mogonono), Burkea africana (Monalo /Musheshe) and Lonchocarpus capassa are the major plant species characterizing the vegetation of the sample plots in Chobe and Kasane Forest Reserves.

3.2. Structure of Chobe and Kasane Forest Reserves

3.2.1. Diameter Class Distribution and Forest Density

The results of diameter class distribution in Chobe and Kasane Forest Reserves are illustrated in Figure 1 and Figure 2 respectively.

It is apparent from Figure 1 and Figure 2 that, the highest numbers of stems are found in the 21-30 cm and 41-50 cm diameter classes for Chobe and Kasane Forest Reserves respectively reflecting a destruction of young trees by fire which is in line with the findings by other workers suggesting that in Chobe forests, 55% of the first year-old shoots of all species are killed by fire [14]. Chobe Forest Reserve, however, showed the highest number of total stems per hectare/tree density (2048 stems/ha) as compared with Kasane Forest Reserve (544 stems/ha) which explains the observed higher basal area and species diversity index in this particular forest. In Chobe Forest Reserve, more number of trees was found in small diameter classes indicating abundance of young trees which is a characteristic of natural forests [25] and manifestation of the ecosystem resilience [26]. This provides an indication that regeneration in the Chobe Forest Reserve was taking place and also that the population structure was stable as compared with Kasane Forest Reserve, which is in agreement with other studies [18, 27]. It also implies that Chobe Forest Reserve with the highest number of young trees has more bright future than the Kasane Forest Reserve.

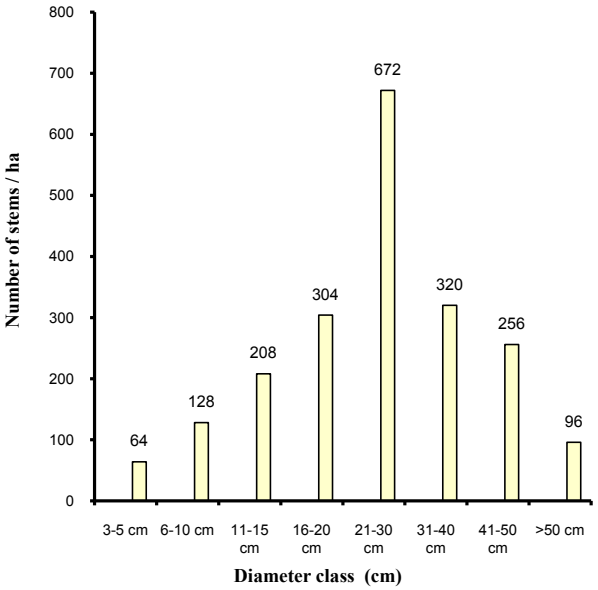

Figure 1. Diameter class distribution of stems in Chobe Forest Reserve

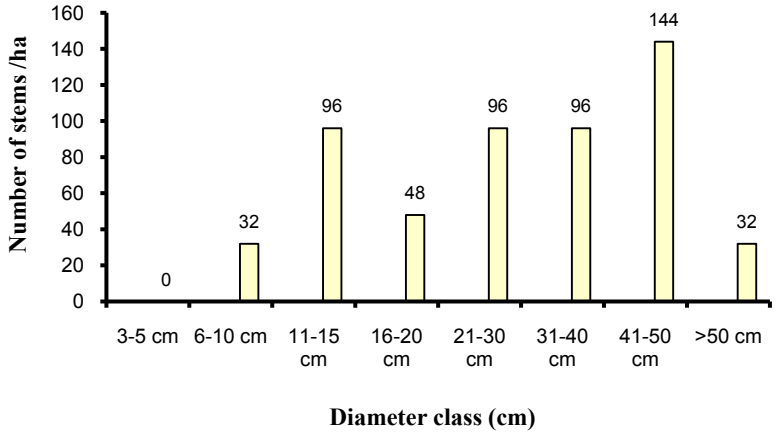

Figure 2. Diameter class distribution of stems in Kasane Forest Reserve

3.2.2. Basal Area and Species Diversity Index

The results of basal area and species diversity are shown in Table 1 and Table 2 respectively. They indicate that Chobe Forest Reserve showed significantly ($P<0.05$) higher basal area and tree species diversity as compared with Kasane Forest Reserve. The basal area of trees in Kasane was reduced by 71.3% as compared to that of Chobe and this might be due to the reported fire outbreak which burnt 8820 ha of forest [28].

Table 1. Basal area in both Chobe and Kasane Forest Reserves of Botswana

Plot No.	Basal area (m^2 ha^{-1})	
	Chobe Forest Reserve	Kasane Forest Reserve
1	24.30	3.10
2	21.80	5.34
3	34.90	2.13
4	14.10	1.74
5	14.80	2.53
6	15.10	5.80
7	7.40	7.20
8	3.30	3.28
9	7.90	5.86
10	2.30	4.95
Total	146.20	41.93
Standard Error of the Mean (SEM)	3.21	0.5914
t-calculated	3.261	
tabulated value $t_{0.05,9}$	1.8331	
t-tabulated < t-calculated	Reject Ho	

A higher Shannon's Index value in Chobe Forest Reserve indicates that there is a greater diversity of species in that particular forest as compared with Kasane Forest Reserve which is in conformity with other studies suggesting that the species diversity increases with the number of species in the community [29, 26] or the larger the value of species diversity index (Shannon's index) the greater the species diversity and vice versa [30]. In this study, the diversity index value is higher than the reported usual range of 1.5-3.5 [29] and those found in other woodlands. Higher values of diversity index indicate greater stability of community [31, 18] suggesting, therefore, that Chobe Forest Reserve had stable structure as compared with Kasane Forest Reserve. An ecosystem with Shannon's index value greater than 2 has been regarded as medium to high diverse in terms of species [32]. The knowledge of tree diversity is, therefore, useful for establishing the influence of human activities and the state of succession and stability in Chobe and Kasane Forest Reserves which is in line with the findings from other studies [33]. Differences in vegetation within and between Chobe and Kasane Forest Reserves may be attributable to geomorphic evolution of landscape [34], soil moisture and nutrients dynamics [35], effect of fire [36, 34], wildlife impacts and past land use [37, 18], successional status [38], competitive interaction and other anthropogenic disturbances [18] as evidenced by studies on other woodlands.

Table 2. Tree species diversity in both Chobe and Kasane Forest Reserves of Botswana

Plot No.	Shannon's Index (H) of diversity per each plot area (0.0625ha)	
	Chobe Forest Reserve	Kasane Forest Reserve
1	0.3050	0.6366
2	0.6277	0.6932
3	0.2990	0.6932
4	1.3300	0.0000
5	0.5660	0.6932
6	1.2060	1.3300
7	0.6365	1.0550
8	0.9004	0.5626
9	1.2210	1.0400
10	0.6365	0.0000
Total	7.7281	6.7038
Standard Error of the Mean (SEM)	0.1183	0.1350
t-calculated	3.710	
tabulated value $t_{0.05,9}$	1.8331	
t-tabulated < t-calculated	Reject Ho	

3.3. Exploitation of Valuable Species and Implications of Their Losses to the Society

It has been observed that about 60% of the total trees recorded in the study area of Chobe Forest Reserve were dead with *Pterocarpus angolensis* (Mukwa) showing the highest mortality rate of 21%. As evidenced by the observed stumps, some of the mature stems of valuable timber tree species (e.g. *Pterocarpus angolensis*, *Baikiaea plurijuga, etc.*) were cut or harvested illegally. *Baikiaea plurijuga* (Mukusi) showed the highest survival rate (76.3%) as compared with other species including *Combretum zeyheri, Pterocarpus angolensis* (Mukwa)*, Combretum gratissimus, Terminalia sericea* (Mogonono)*, Burkea africana* (Monalo/Musheshe) and *Lonchocarpus capassa*. It was also observed that 16.3% of the living trees (i.e. 40% of the total trees) in Chobe Forest Reserve were wounded by either fire or elephant. In Kasane Forest Reserve, however, 26.5% of the total living trees were wounded representing an increase in wounded trees of 38.5% (from 16.3 to 26.5% wounded trees).

The increased tree mortality rate in both Chobe and Kasane Forest Reserves and the observed land degradation and forest cover disappearance attributable to the increased fire incidences in Botswana (e.g. During the 1991-2003 period, 1435 fires burnt 8.5 million hectares) [11, 28] and elephant population (e.g. The 6.41 elephant km^{-2} in Chobe

exceeds the land carrying capacity of 0.4 elephant km^{-2}) [16] are in agreement with the findings from other studies suggesting that the combined effects of fire and elephant damage threatens the long-term sustainability of Chobe forests [7-16]. This is also in agreement with the reports suggesting that tree damage (i.e. debarking, breaking and pushing trees) by elephants increase its susceptibility to further damage from fungi, disease, drought and fire [39, 2, 14, 10]. The reduced number of *Pterocarpus angolensis* in both forests can also be attributed to the selective and unsustainable logging operations [17], dieback disease problems, soil physical, chemical and biological properties and variation in water table.

Based on the lost *Pterocarpus angolensis* (21% of trees) and the reported 26% recovery rate of saleable timber [39] and the current market price (BWP 3399 m^3) of this valuable species in Gaborone (i.e. refer to the price offered by Terry Cooney Timber Company in 2003) it can be noted that a total of Botswana Pula 258291.9 (US $ 86,097.3) was lost per hectare due to fire and elephant damage. In addition to the loss of this money which was supposed to help the rural people improving their health condition, especially that of the most vulnerable women and children, both the intangible goods and services provided by this indigenous species are also being lost.

4. Conclusions and Recommendations

It is concluded that Pterocarpus angolensis (Mukwa), Baikiaea plurijuga (Mukusi), Combretum zeyheri, Combretum gratissimus, Terminalia sericea (Mogonono), Burkea africana (Monalo / Musheshe) and Lonchocarpus capassa dominate the vegetation of Chobe and Kasane Forest Reserves. Chobe Forest Reserve, however, is high diverse in terms of species and more stable as compared with Kasane Forest Reserve. Abundance of young trees (i.e. a characteristic of natural forests) in Chobe Forest Reserve provides an indication that regeneration in the forest reserve was taking place and also that the plant population structure is stable. It also implies that Chobe Forest Reserve with the highest number of young trees has more bright future than Kasane Forest Reserve. Human activities (eg. illegal and selective harvesting of valuable species) and plant damage by other biotic factors are responsible for the observed losses of valuable indigenous species such as Pterocarpus angolensis, increased land degradation and suppressions of natural regenerations. To reduce the risk of damage from future biotic and abiotic disturbances on Botswana's forest resources, therefore, there is a need for harmonizing societal needs, resource potential and institutions guiding resource use, effective and sustainable forest management, forest conservation and enhancement of forest carbon stocks. More detailed studies, however, are required to determine the species richness (relative density), abundance (relative dominance), importance value index, diversity, volume distribution and canopy cover of all Botswana forests. Qualitative and quantitative data on the destructive impacts of biotic and abiotic disturbances are also urgently needed. Fire management plan and policy also need to be developed.

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