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Full Length Research Paper

Impacts of local-level utilization pressure on the structure of mopane woodlands in Omusati region, Northern Namibia

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A comparative analysis of mopane woodland structure under different utilization pressure was done in Omusati region, northern Namibia. Heights, basal area, biomass and densities of trees, shrubs and stumps were compared between a game park, densely-populated (central) and sparsely-populated (western) areas. Heavy utilization significantly reduced tree basal area, biomass and plant densities in central Omusati, leading to an unsustainable situation. Woodland recovery from previous disturbance in the game park has been slow. Contrary to expectation, there were fewer dead stumps in central area because of continual harvesting due to firewood scarcity. Height structure differed significantly with more than expected numbers of plants in the ≤ 1 m, 1.1 to 2 m and less than expected plants in the 3.1 to 4 m and 4.1 to 5 m height classes in central Omusati. More than expected numbers of trees were recorded in 4.1 to 5 m height class in western area and in 2.1 to 3 m and 3.1 to 4 m height classes in Game Park. This indicates over-harvesting of medium-sized trees in central Omusati. Mopane regenerates profusely through coppicing. However, no relationship existed between stump size and number of shoots due to continual harvesting of shoots, especially in central area. Proper coppice management and pollarding strategies should be implemented to improve the situation.

Key words: C*olophospermum mopane*, coppicing, Omusati, woodland structure, woodland utilization.

INTRODUCTION

Forests and woodlands play important roles in the livelihoods of many societies, especially in communal areas where direct dependence on natural resources is high. In addition to performing many ecological functions,woodlands and forests provide many goods and services that are essential for improving and maintaining human livelihoods (Association of Women Foresters of Burkina (AMIFOB) et al., 2004; Campbell and Marsh, 2000; Mandondo, 2001; Mazambani, 1992). They also play important roles in local cultures and economies of many communities (Nkem et al., 2008; Fotso, 1998), especially in the developing world, where poverty levels are high. However, there have been growing concerns on woodland and forest decline and degradation caused by various factors including unsustainable harvesting practices by resource users. As a result, the need for sustainable use of natural resources has been placed high on the priorities of most governments as the world faces an ever-increasing human population which puts pressure on limited natural resources. This need was underlined by the World Commission on Environment and Development (1987) and subsequently, United Nations Conferences on Environment and Development and numerous other platforms.

The problem of resource degradation is more acute in Africa where a significant proportion (40%) of the people live in abject poverty and rely heavily on natural resources for survival. Sustainable utilization of woodland and forest resources, as well as their conservation have

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been inherent in the practices of many local communities for centuries (Niamir, 1990) but increasing population pressure and poor management practices have led to degradation of woodlands and forests in many parts of the world, especially those managed as open access resources. Such resources need to be properly managed to ensure sustained provision for local household needs. The situation has been aggravated and made more complex by relatively new challenges such as HIV/AIDS (Shackleton et al., 2006) and climate change (Scholes et al., 2008; Nkem et al., 2008).

Southern Africa is endowed with woodland resources which have sustained millions of people for centuries, particularly rural peasants. These include *Brachystegia*-dominated (miombo), *Acacia*-dominated (thorn), *Baikiaea plurijuga*-dominated (Zambezi teak) and *Colophospermum mopane*-dominated (mopane) woodlands. Most woodlands occurring in communal areas are under increasing pressure (Chidumayo, 2002; Musvoto et al., 2007) due to human population expansion. Mopane woodlands are especially important in arid and semi-arid areas of southern Africa where they cover large expanses of land (Mapaure, 1994; Timberlake, 1996). Due to increasing awareness of the importance of mopane woodlands in these areas, many initiatives are underway to provide some degree of support to local communities whose livelihoods depend on these woodlands for both wood-based and non-wood products. Such initiatives have mostly involved management of the mopane caterpillar (*Imbrasia belina)* which is a nutritious delicacy and less so on other woodland resources.

In Namibia, mopane woodlands occur mostly in the northern parts of the country, which are home to at least 60% of the population. These woodlands cover about 77000 km^2 in the country (Mapaure, 1994). They are more extensive in Omusati region, whose name ‘omusati’ is the local name for mopane. Concern has been expressed on the dwindling woodland resources due to human pressure. In Omusati region in particular, the Directorate of Forestry expressed concern that woodland use seemed unsustainable (Selänniemi et al., 2000) but no empirical data exist to substantiate this. It was in view of this concern that this study was carried out in Omusati region to assess the state of mopane woodlands and get insights about the sustainability of utilization practices in the region by comparing areas under different levels of human pressure.

MATERIALS AND METHODS

Study area

The study was done in Omusati region, northern Namibia (Figure 1). Omusati is one of the thirteen political regions of Namibia and covers 26573 km^2. Kunene region bound Omusati region in the west and south, Oshana and Ohangwena regions in the east and Angola in the north. Omusati has a human population of about 229000 and has a high overall population density of close to 9 persons/km^2 (National Planning Commission, 2007), ranging between 1.8 and 54.6 persons/km^2. Two communal sites were selected for study based on differences in the population densities and living styles of the respective ethnic groups: A sparsely populated western Omusati site (occupied by predominantly OvaHimba ethnic group) and a densely-populated central Omusati (occupied by Owambo ethnic group). The Ogongo game park, a protected area without human habitation, was the third site. These sites experience different utilization levels, with central Omusati been heavily utilized compared with the western area and the game park (Mapaure and Ndeinoma, 2008).

Topography is characterised by flat plains, which form part of the Etosha depression. In the western part, the land rises gently to the foothills of the Kaokoland. Annual rainfall ranges between 450 and 500 mm in the northeast and 250 and 300 mm in the southwest (NPC, 2007). Mean maximum and mean minimum temperatures range between 32 and 34°C, and 6 to 8°C, respectively. The vegetation is classified into four broad types (Selänniemi et al., 2000) as palm savanna, bush mopane savanna, seasonally flooded grasslands and patches of mopane and *Acacia* and open shrub savanna of Mopane and *Acacia*. Only mopane woodlands were selected for study.

Vegetation assessments

These assessments were done only in woodlands dominated by *Colophospermum mopane*. Fifty-eight plots were demarcated, 21 in central Omusati, 18 in western Omusati and 19 in the Ogongo game park. Trees and stumps were assessed in plots measuring 20 x 20 m, while 5 x 5 m subplots nested within the larger plots were used for shrub assessments. Trees and shrubs were defined according to Anderson and Walker (1974). A total of 752 trees, 283 shrubs, 178 dead stumps and 699 live stumps were assessed in all the three sites combined (Central: 85 trees, 123 shrubs, 71 dead stumps, 547 live stumps; Western: 335 trees, 58 shrubs, 81 dead stumps, 100 live stumps; Game park: 332 trees, 102 shrubs, 26 dead stumps, 52 live stumps). All plants were identified; basal circumferences and heights of trees were measured using a tape measure and a ranging pole, respectively. For multi-stemmed trees, the basal circumference of each stem was measured separately and the total basal area for the tree was calculated. Of all woody plants assessed, 87.2% were *C. mopane*. Stumps were also identified and assessed whether they were dead or alive. Basal circumferences of all live stumps were measured and the number of coppice shoots on each stump was recorded. Shrub heights were measured and all stems on each shrub were counted.

Data analyses

The biomass of each tree was calculated using the formula derived for mopane woodlands in northern Botswana by Tietema (1989):

$$\text{Mass (in kg)} = 0.0644*(\text{basal area, in cm}^2)^{1.3341}$$

The basal area was then expressed in t/ha for each plot. Differences in biomass, basal areas and densities among the sites were tested using One-way ANOVA after testing for normality. *Post hoc* analyses were done using Tukey’s test. Differences between individual plants and stems at each site were tested using a paired t-test. Linear regression analysis was used to test whether the number of coppice shoots on each stump depended upon stump size. Other curve-fit models (exponential, cubic, quadratic and logarithmic) were also tested to determine the best model to describe the relationship. Differences in frequency distribution patterns of woody plant heights among sites were tested by a χ^2-

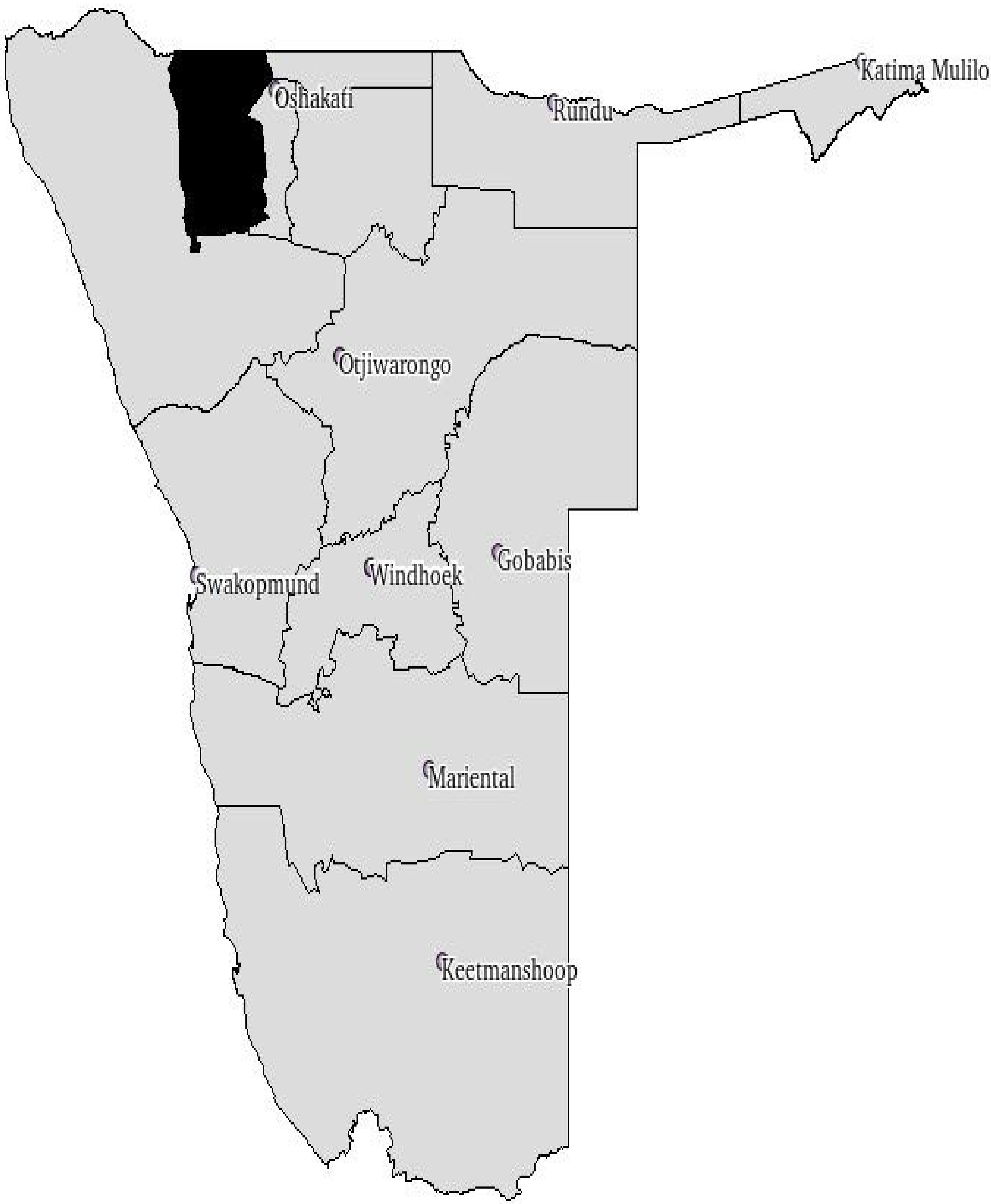

Figure 1. Location of Omusati region (shaded area) in Northern Namibia.

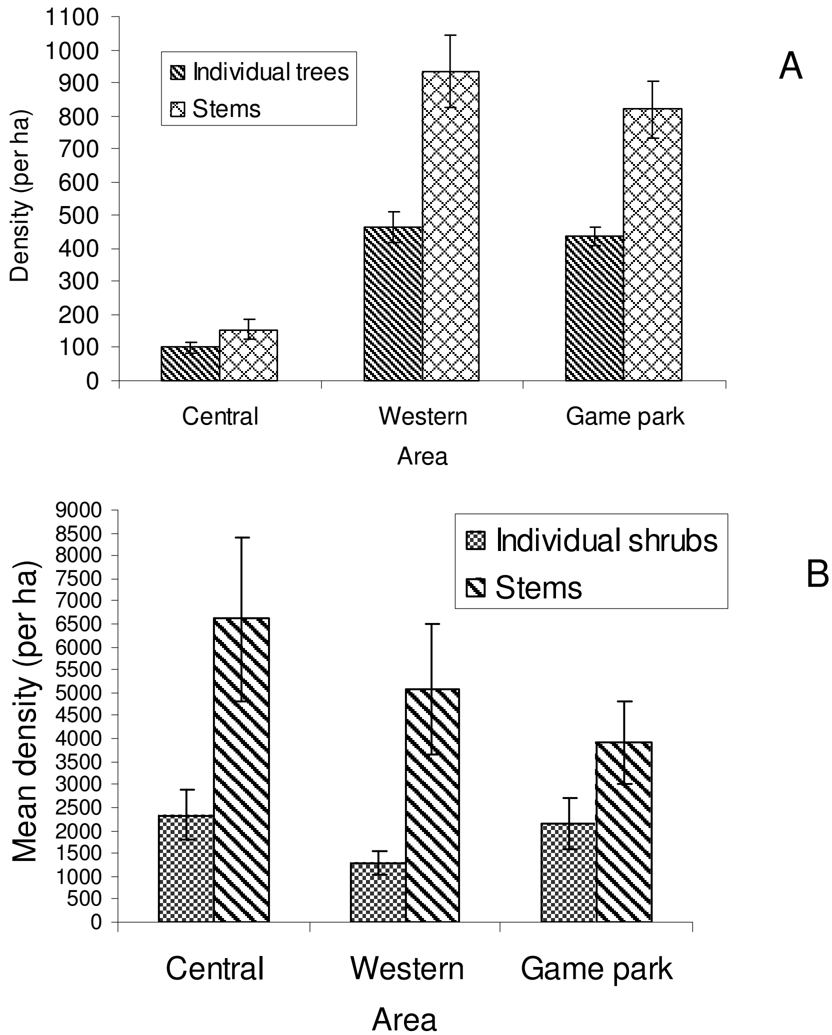

Figure 2. Differences in the densities of individuals and stems of trees (a) and shrubs (b) in mopane woodlands at three sites in Omusati region, Northern Namibia.

test.

RESULTS

Differences in plant densities and height structure

There were significant differences in tree densities among the three sites ($F = 43.68$, $p < 0.001$): the western area and game park had significantly higher tree densities than the central area ($p < 0.001$). There was no significant difference between the western area and the game park (Figure 2a). Stem densities were significantly higher than individual tree densities in the central area ($t = 3.116$, $p < 0.01$), western area ($t = 6.240$, $p < 0.001$) and in the Game park ($t = 5.775$, $p < 0.001$) (Figure 2a). Stem densities also differed significantly among the three sites ($F = 30.10$, $p < 0.001$): the western area and the game park had significantly higher density than the central area ($p < 0.001$). There were no significant differences in stem densities between the western area and the Game Park. Shrub stem densities were significantly higher than individual shrubs in the central ($t = 3.171$, $p < 0.01$), western ($t = 2.987$, $p < 0.01$) and Game park ($t = 4.305$, $p < 0.001$) (Figure 2b). There were no significant differences in each of these two variables among sites.

Most stumps encountered (98.6%) were *C. mopane*. Other stumps recorded were *Combretum apiculatum*, *Combretum collinum*, *Kirkia acuminata*, *Terminalia prunioides* and *Acacia nilotica*. Densities of dead stumps differed significantly among sites ($F = 4.48$, $p < 0.05$) (Figure 3), with higher densities in the western area than in the game park ($p < 0.05$). Not all other comparisons

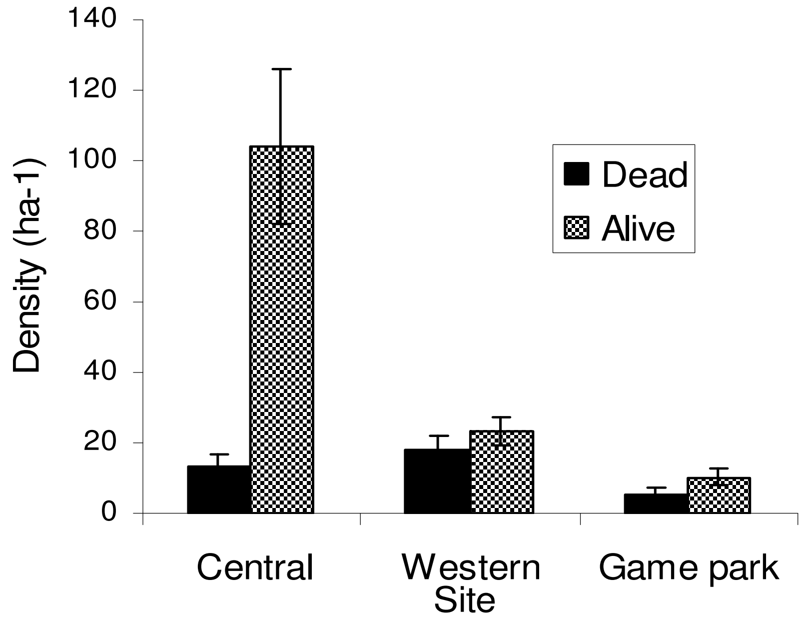

Figure 3. Differences in the densities of dead and live stumps in mopane woodlands at three sites in Omusati region, Northern Namibia.

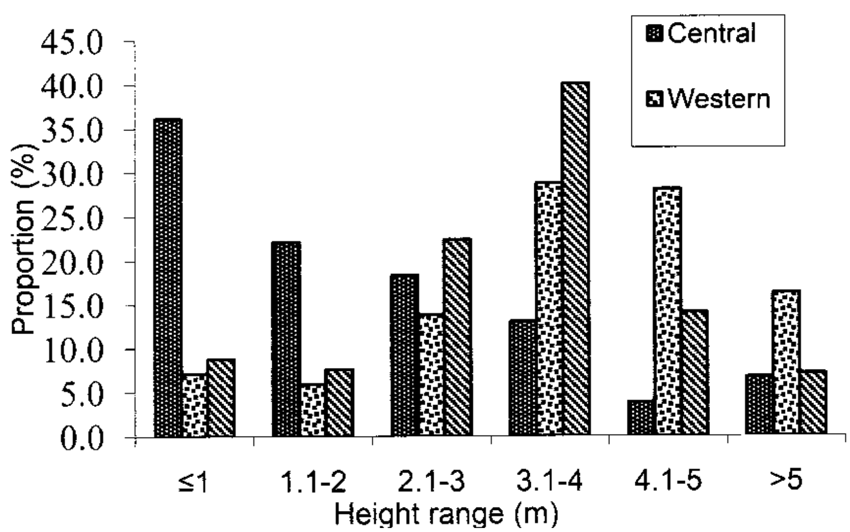

Figure 4. Differences in the height frequency distribution patterns of woody plants in mopane woodlands at three sites in Omusati region, Northern Namibia.

were significant. Densities of live stumps also differed significantly among sites ($F = 13.70$, $p < 0.001$) (Figure 3), with significantly higher density in the central area than at the other two sites ($p < 0.001$). There was no significant difference in live stump densities between the western area and the Game park. Densities of live stumps were significantly higher than dead stumps in the central area ($t = 2.02$, df = 40, $p < 0.001$). No significant differences were recorded at the other two sites.

The highest proportion of woody plants recorded in the western area and the game park were 3.1 to 4 m tall, while the central area had the highest proportion in the ≤ 1 m height class. Very few woody plants were >5 m tall at all sites (Figure 4). There were significant differences in the height frequency distribution patterns of woody plant heights among sites ($\chi^2 = 250.12$, df = 10, $p < 0.001$). Much less than expected number of plants was recorded in the height classes 3.1 to 4 m and 4.1 to 5 m in the

Table 1. Differences in the mean tree basal area and mean biomass in mopane woodlands at three sites in Omusati region, Northern Namibia.

Site	Mean tree basal area (±SE) (m^2/ha)	Mean tree biomass (±SE) (t/ha)
Central	2.31 (±0.58)[a]	18.26 (±5.62)[a]
Western	9.07 (±1.26)[b]	96.72 (±17.58)[b]
Game park	6.89 (±0.92)[b]	66.95 (±11.64)[b]
Significance	$p < 0.001$	$p < 0.001$

Different superscripts for each variable indicate significant differences between the sites.

central area and in the ≤1 m category in the western area and the Game park. Significantly, more than expected number of plants was recorded in the ≤ 1 m and 1.1 to 2 m height classes in the central area, 4.1 to 5 m height class in the western area and 2.1 to 3 and 3.1 to 4 m height classes in the Game park.

Variations in tree basal areas and biomass

There were significant differences in tree basal areas amongst sites ($F = 14.13$, $p < 0.001$) (Table 1), with significantly lower basal area in the central than the western area ($p < 0.001$) and than in the Game park ($p < 0.01$). The same pattern was true for tree biomass comparisons ($F = 10.997$, df = 2, $p < 0.001$; Table 1).

Mopane regeneration from coppice

All the 547 live *C. mopane* stumps recorded in the central area were coppicing. There was an average of 5.4 ± 0.2 coppice shoots per stump. All the 100 live stumps of mopane recorded in the western area were also coppicing, with an average of 5.0 ± 0.2 shoots per stump. In the Game park, 52 mopane stumps were recorded and all of them were coppicing, with an average of 5.5 ± 0.4 shoots per stump. In general, large-sized stumps supported more coppice shoots than smaller-sized stumps but within a limited size range of less than 80 cm circumference (Figure 5). Linear regression analysis showed a weak relationship ($r^2 = 0.295$, $F = 294.65$ $p < 0.001$) between number of coppice shoots and stump size. All other curve-fit models tested were weaker than the linear model.

DISCUSSION

Impact of woodland utilization on vegetation structure

This study has clearly demonstrated that mopane woodlands in central Omusati are structurally different from those of both the protected Game park and western Omusati. This trend is not unexpected in communal areas where population density is high (13.9 persons/km^2 in central Omusati) and where resource management regimes are open access in nature. Nevertheless, the extent to which the woodlands have changed in central Omusati compared with the neighbouring two sites is a cause for concern. The fact that live stump densities in the central area were 342 and 910% higher than western area and Game park, respectively, is clear testimony of heavy utilization pressure. Mapaure and Ndeinoma (2008) reported that, utilization pressure has negatively impacted on the species composition and diversity of woodlands in central Omusati compared with the other two sites. Densities of dead stumps in the central area are under-estimates because most of the stumps are also harvested for firewood, a situation that normally manifests itself under resource scarcity conditions. Subsistence harvesting of woody plants by local communities in various sites in southern Africa has been shown to result in significant changes in the structure of woodlands (Luoga et al., 2004) which in turn negatively impacts on local livelihoods. In the current study, reductions in tree biomass in central Omusati ranged between 72 and 82% which are much higher than a decrease of 32.5% mopane woody biomass in Dukwe, Botswana reported by Tietema (1993a, b).

Considering that western Omusati and the Game park are also experiencing or have also experienced wood harvesting, changes recorded in central Omusati are under-estimates of the actual situation because there is no true experimental control in this investigation. It is not reasonable to directly compare values of woodland parameters across the whole mopane woodland range because of the high variability and heterogeneity of woodland use at different sites. For instance, the biomass of unharvested mopane woodland in Dukwe, Botswana, recorded by Tietema (1993a, b) was 117 t/ha, while values recorded from Zimbabwe (under various management scenarios) ranged between 15 and 68 t/ha (Kelly and Walker, 1976; Guy, 1981; Grundy et al., 1993). Cunningham (1993) emphasized that, patterns of woodland use and depletion vary according to settlement patterns, abundance and patchiness of favoured plant species and their sizes. It is conceded though, that the palisade structure of Owambo huts consumes more

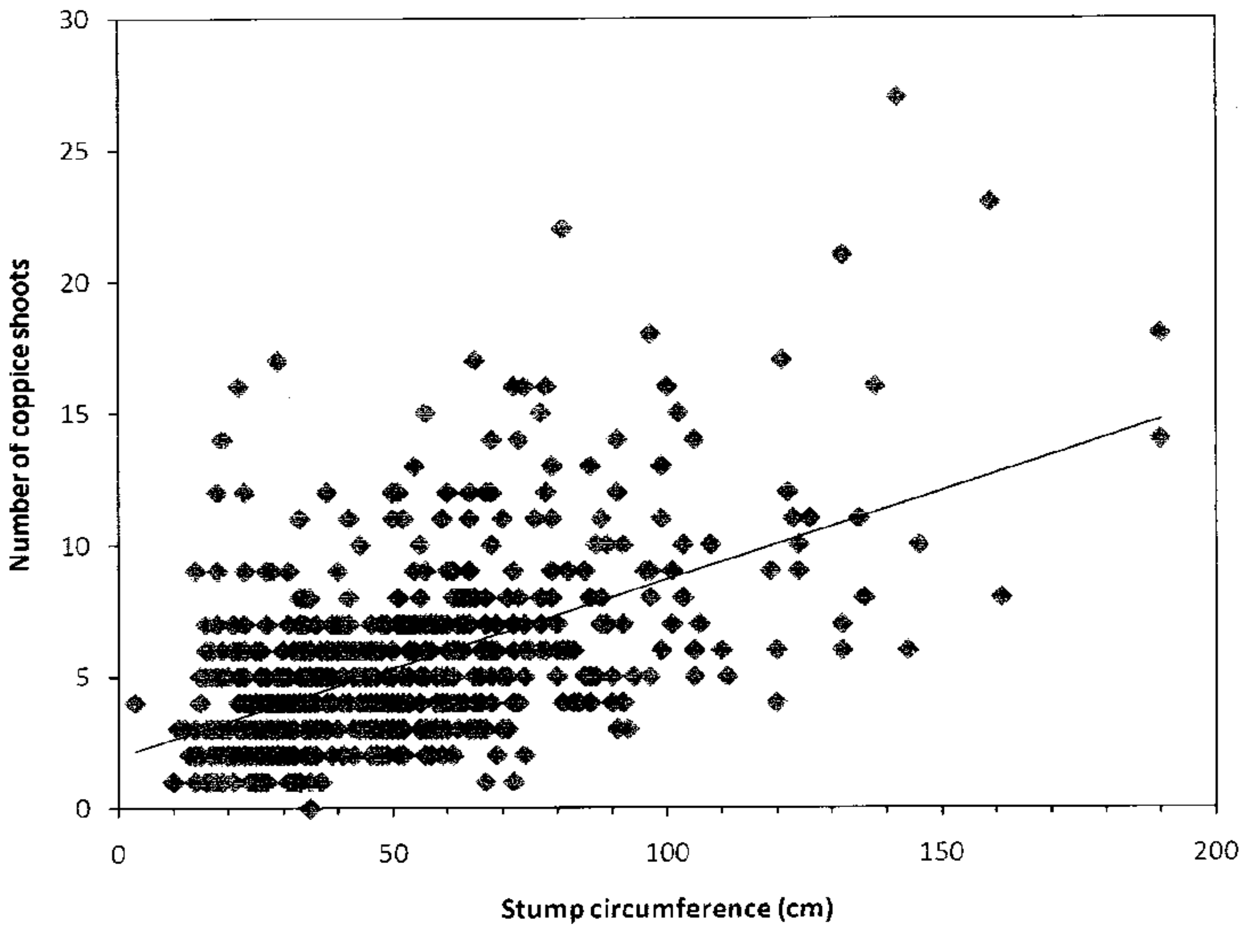

Figure 5. The relationship between mopane stump circumference and the number of coppice shoots supported by the stump.

wood than any other structure in southern Africa (Erkillä and Siiskonen, 1992), a situation that explains over-harvesting of pole-sized plants in central Omusati. The lack of expected numbers of trees in height class 3.1 to 5 m and the dominance of younger trees (Figure 5) is clear evidence of preferential harvesting of the pole-sized trees for household use. It is a well-known pattern that communities prefer certain sizes of trees for construction of timber and firewood (Grundy et al., 1993). The demand for wood resources depends not only on human population densities but also on the replacement times of construction timber.

The dominant growth form of mopane is usually single-stemmed (Frost et al., 1987) but multi-stemmed shrub formations also occur (Gelens, 1996; Hempson et al., 2007). The inventoried sites had no naturally shrub-like forms (Gelens, 1996) which normally occur on soils of high sodicity and high impermeability (Thompson, 1960 cited in Gelens, 1996). These results indicate that, the majority of trees were multi-stemmed, a situation normally resulting from resprouting in response to disturbance. Resprouting allows plants to recover quickly without having to set seed. The importance of resprouting as a survival strategy in plants has been recorded from a variety of habitats worldwide (Basnet, 1993; Lamont and Markey, 1995). However, one cost of producing multiple stems is that tree height is compromised (Nzunda et al., 2007) as observed in this study. Multi-stemming was lower in central Omusati than at the other two sites, an observation which could indicate that in central Omusati, most of the stems produced by an individual plant were harvested (due to higher demand), whereas they persisted longer in the other two areas. In western Omusati, it may be a deliberate management practice to conserve woodlands by local communities, being a predominantly cattle-rearing (rather than crop-farming) ethnic group whose hut structures are more basic than those of Owambo. The existence of multi-stemming and occurrence of stumps in the game park shows that, these woodlands have not fully recovered from previous disturbance since the mid-1990s when an army base moved out of the area. Occassional illegal harvesting of wood from the Game park by adjacent farmers still takes place.

Tree basal area and tree biomass are positively related (Timberlake, 1995) thus, reductions in biomass manifest themselves in a similar pattern as in basal area (Table 1). Differences in basal area should be interpreted in conjunction with the frequency distribution pattern in order to get a cleareroverall pattern. In central Omusati, the pattern is indicative of a woodland dominated by smaller trees, disproportionately fewer individuals in the middle-size classes and much higher than expected numbers of large trees. This is indicative of over-harvesting of certain targeted sizes of plants. As preferred plant sizes become scarcer, non-preferred sizes are also harvested, leading to woodland degradation.

Results indicate that *C. mopane* coppices profusely. Other researchers (Gelens, 1996; Mushove, 1993; Mlambo and Mapaure, 2006; Mushove and Muchichwa, 1996; Timberlake, 1995) have reported this characteristic from several sites. Luoga et al. (2004) and Grundy (1996) reported that, coppicing effectiveness was dependent upon plant size, stump height, age of rootstock and percentage of woodland stand removed. The study results indicate that, mopane is a very resilient species, which with proper management, can be sustainably maintained to provide required goods for local communities without significant degradation. However, the growth rate of this species is extremely slow (Grundy, 1996). Coppice shoots grow a little faster than growth from seedlings (Tietema et al., 1988; Erkkila and Siiskonen, 1992), a characteristic that can be taken advantage of in managing the woodlands.

Sustainability of woodland use

From the preceding account, it is evident that woodlands in central Omusati have been over-utilized and degraded due to human pressure. Species composition has changed and species diversity has declined (Mapaure and Ndeinoma, 2008), tree density, tree biomass and tree basal area have all declined primarily due to unsustainable human use. Scarcity of wood resources is evident in central Omusati and there are records of people travelling to western Omusati to harvest wood and other resources. Such activities were already recorded in the early 1990s (Erkilla and Siiskonen, 1992) but the incidences have intensified in the last few years (Musvoto et al., 2007). All these are indications of resource scarcity and a non-sustainable situation. However, from this study, it is not easy to calculate sustainable harvesting regimes that would encourage mopane woodlands in central Omusati to recover and provide enough for local communities. To infer sustainability, there is need to carry out repetitive measurements of these structural attributes over few years. Nevertheless, the assertion by Selanniemi et al. (2000) that woodland use in Omusati appeared to be non-sustainable was confirmed.

Unless local communities start to manage these woodlands through proper coppice management, pollarding, thinning and other practices (Gondo et al., 2007; Musvoto et al., 2006), the situation is bound to worsen. Such practices have been recommended as better technical options in similar situations in Zimbabwe (Gondo et al., 2007). However, the problem of woodland degradation should not be tackled in isolation; instead, it must be considered in a holistic and integrated manner with other challenges of poverty, the HIV/AIDS pandemic and climate change. All these are important drivers of patterns of woodland utilization by local communities.

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REFERENCES

Anderson GD, Walker BH (1974). Vegetation composition and elephant damage in the Sengwa Wildlife Research Area, Rhodesia. J. S. Afr. Wildlife. Manage. Assoc., 4: 1-14.

Association of Women Foresters of Burkina (AMIFOB), Campbell B, Frost P, Kokwe G, Le Breton G, Shackleton S, Tiveau D (2004). Making dry forests work for the poor in Africa – building on success. Forest Livelihood Briefs No. 3: Centre for International Forestry Research (CIFOR), Bogor, Indonesia, pp. 1-4.

Basnet K (1993). Recovery of a tropical forest after hurricane damage. Vegetation, 109: 1-4.

Campbell B, Marsh A (2000). Forests and woodlands products uses and values. In: McCullum H (ed). Biodiversity of indigenous forests and woodlands in southern Africa, SADC, IUCN, SARDC, Maseru and Harare, pp. 107-136.

Chidumayo EN (2002). Changes in miombo woodland structure under different land tenure and use systems in central Zambia. J. Biogeog., 29: 1619-1626.

Cunningham AB (1993). Low-cost housing needs, wood use and woodlands. In: Pearce GD, Gumbo DJ (eds.) The ecology and management of indigenous forests in southern Africa. Proceedings of an International Symposium, Victoria Falls, Zimbabwe, 27-29 July 1992. Forestry Commission, Harare, pp. 283-291.

Erkillä A, Siiskonen H (1992). Forestry in Namibia 1850-1990. Silva Carelica 20. University of Joensuu, Finland, pp. 149-165.

Fotso RC (1998). Two models for the conservation of biodiversity and for community development in Cameroon. In: Christoffersen N, Campbell B, du Toit J (eds) Communities and sustainable use: Pan-African perspectives. Proceedings of the Pan-African Symposium on the sustainable use of natural resources and community participation. Harare, Zimbabwe, pp. 97-102.

Frost PGH, BSc Hons students (1987). Damage to mopane,

Colophospermum mopane, in relation to elephant density at Kariba. Unpublished report. Department of Biological Sciences, University of Zimbabwe, Harare, pp. 1-17.
Gelens M (1996). Mopane shrubland management in northern Namibia. In: Flower C, Wardell-Johnson G, Jamieson A (eds) Management of mopane in southern Africa. Proceedings of a Conference held at Ogongo Agricultural College, Namibia, 26-29 November, 1996. ODA/Directorate of Forestry, Windhoek, pp. 21-27.
Gondo T, Musvoto C, Mujawo T (2007). Social preferences to mopane woodland management options: A case study from southern Zimbabwe. Discov. Innov., 19: 4-14.
Grundy I (1996). Woodland management strategies fo communaly-owned mopane woodland in the Zambezi Valley, Zimbabwe: An alternative to commercial logging. In: Flower C, Wardell-Johnson G, Jamieson A (eds) Management of mopane in southern Africa. Proceedings of a Conference held at Ogongo Agricultural College, Namibia, 26-29 November, 1996. ODA/Directorate of Forestry, Windhoek, pp. 45-54.
Grundy I, Campbell BM, Balebareho S, Cunliffe R, Tafangenyasha C, Fergusson R, Parry D (1993). Availability and use of trees in Mutanda Resettlement area, Zimbabwe. For. Ecol. Manage., 56: 243-266.
Guy PR (1981). The estimation of above-ground biomass of the trees and shrubs in the Sengwa Wildlife Research Area, Zimbabwe. S. Afr. J. Wildlife Res., 11: 135-142.
Hempson GP, February EC, Verboom GA (2007). Determinants of savanna vegetation structure: Insights from Colophospermum mopane. Austr. Ecol. 32: 429-435.
Kelly RD, Walker BH (1976). The effects of different forms of land use on the ecology of a semi-arid region in south-eastern Rhodesia. J. Ecol. 64: 553-576.
Lamont BB, Markey A (1995). Biogeography of fire-killed and resprouting Banksia species in south-western Australia. Aust. J. Bot., 43: 283-303.
Luoga EJ, Witkowski ETF, Balkwill K (2004). Regeneration by coppicing (resprouting) of miombo (African savanna) trees in relation to land use. For. Ecol. Manage., 189: 23-35.
Mandondo A (2001). Use of woodland resources within and across villages in a Zimbabwean communal area. Agric. Hum. Values, 18: 177-194.
Mapaure I (1994). The distribution of Colophospermum mopane (Leguminosae- Caesalpinoideae) in Africa. Kirkia, 15: 1-5.
Mapaure I, Ndeinoma A (2008). Impacts of utilization on the composition and diversity of mopane woodlands in northern Namibia. Paper presented at an International Symposium on Sustainable forest management in Africa: African solutions to African problems in sustainable natural forest management. Stellenbosch University, South Africa; 3-7 November.
Mazambani D (1992). Aspects of the use of indigenous wood biomass resources in Zimbabwe's communal lands: A case study from Chivi and Zvishavane Districts. In: Pearce GD, Gumbo DJ (eds.) The ecology and management of indigenous forests in southern Africa. Forestry Commission, Harare, pp. 292-300.
Mushove PT, Muchichwa J (1996). Appropriate silvicultural intervention for improved growth in Colophospermum mopane. In: Mushove PT, Shumba EM, Matose F (eds.) Sustainable management of indigenous forests in the dry tropics. Forestry commission/SAREC, Harare, p. 226.
Musvoto C, Mapaure I, Gondo T, Ndeinoma A, Mujawo T (2007). Reality and preferences in community mopane (Colophospermum mopane) woodland management in Zimbabwe and Namibia. Proc. World Acad. Sci. Eng. Tech., 22: 83-87.
National Planning Commission (2007). Regional Poverty Profile: Omusati. Based on village-level Participatory Poverty Assessment in Omusati Region, Namibia, December 2005-February 2006. Summary Report, Windhoek, pp. 6-8.
Niamir M (1990).Traditional woodland management techniques of African pastoralists. Unasylva, 41: 160: 49-58.
Nkem J, Idinoba M, Brockhaus M, Kalame F, Tas A (2008). Adaptation to climate change in Africa: Synergies with biodiversity and forest. Environment Brief No. 3, Centre for International Forestry Research (CIFOR), Bogor, Indonesia, pp. 1-4.
Nzunda EF, Griffiths ME, Lawes MJ (2007). Multi-stemmed trees in subtropical coastal dune forest: Survival strategy in response to chronic disturbance. J. Veg. Sci., 18: 693-700.
Scholes RJ, Ajavon AL, Nyong T, Tabo R, Vogel C, Ansorge I (2008). Global Environmental Change (including climate change and adaptation) in sub-Saharan Africa. International Council for Science Regional Office for Africa (ICSU ROA) Science Plan, Pretoria, pp. 9-16.
Selänniemi T, Chakanga M, Angombe S (2000). Inventory Report on the Woody Resources in the Omusati Region. Directorate of Forestry. Windhoek, pp. 35-38.
Shackleton S, Kaschula S, Twine W, Hunter L, Holding-Anyonge C, Petheram L (2006). Forests as safety nets for mitigating the impacts of HIV/AIDS in southern Africa. Forest Livelihood Briefs No. 4: Centre for International Forestry Research (CIFOR), Bogor, Indonesia, pp. 1-4.
Thompson JG (1960). A description of the growth habits of mopani in relation to soil and climatic conditions. Proceedings of the First Federal Science Congress, Salisbury, Southern Rhodesia, Harare, pp. 181-186.
Tietema T (1989). Biomass determination of fuel wood trees and bushes of Botswana, Southern Africa. For. Ecol. Manage., 60: 257-269.
Tietema T (1993a). Possibilities for the management of indigenous woodlands in southern Africa: A case study from Botswana. In: Pearce, GD, Gumbo DJ (eds.) The ecology and management of indigenous forests in southern Africa. Proceedings of an International Symposium, Victoria Falls, Zimbabwe, 27-29 July 1992. Forestry Commission, Harare, pp. 134-143.
Tietema T (1993b). Biomass determination of fuel wood trees and bushes of Botswana, Southern Africa, For. Ecol. Manage., 60: 257-269.
Tietema T, Kgathi DL, Merkesdal E (1988). Wood production and consumption in Dukwe: A feasibility study for a woodland management and plantation scheme. NORAD/NIR, Gaborone, Botswana, p. 86.
Timberlake J (1995). Colophospermum mopane: an annotated bibliography and review. Zimbabwe Bullettin of Forestry Research No. 11, Forestry Commission, Harare, pp. 1-49.
Timberlake J (1996). A review of the ecology and management of Colophospermum mopane. In : Flower C, Wardell-Johnson G, Jamieson A (eds) Management of mopane in southern Africa. Proceedings of a Conference held at Ogongo Agricultural College, Namibia, 26-29 November, 1996. ODA/Directorate of Forestry, Windhoek, pp. 10-16.
World Commission on Environment and Development (1987). Our common future. Oxford University Press, Oxford, pp. 27-66.