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Tree species composition, structure and utilisation in Maruzi Hills Forest Reserve in Uganda

I Kiyingi[1]*, JM Kidiya[1], S Gwali[1], P Okullo[1] and DM Byabashaija[1]

[1] National Forestry Resources Research Institute, PO Box 1752, Kampala, Uganda
** Corresponding author, e-mail: ikiyingi_2000@yahoo.com*

The study investigated the tree species composition, vegetation structure and harvesting pattern to guide management of the Maruzi Hills Forest Reserve. Stratified random sampling was used to site six (100 m × 100 m) permanent sample plots in the woodland, bushland and grassland vegetation types identified in the reserve. Rényi diversity profiles indicated that bushland vegetation had a lower Shannon diversity index ($H = 2.054$) than grassland ($H = 2.38$) and woodland vegetation ($H = 2.319$). Grassland and woodland vegetation also had lower proportions of the dominant species ($\alpha_\infty = 1.15$ and 1.66, respectively) than bushland vegetation ($\alpha_\infty = 3.25$). However, the mean stem density of the woodland, bushland and grassland vegetation was 214 stems ha^{-1}, 191 stems ha^{-1} and 114 stems ha^{-1}, respectively. Bray-Curtis and Jaccard ecological distance matrices showed that, although the three vegetation types shared some common species, the ecological distances were relatively high suggesting significant species composition variation between the vegetation types, particularly between the bushland and the other vegetation types. The species with the highest proportional abundance in the survey were *Combretum molle* (23%), *Acacia hockii* (17.7%), *Combretum collinum* (16.1%), *Grewia mollis* (6.5%) and *Lannea barteri* (6.5%). Diameter size-class distribution of woody perennials and tree stumps indicated higher frequencies of the smaller-diameter size classes. The stump records were indicative of charcoal burning and firewood collection as major causes of tree/shrub harvesting. The Maruzi Hills woodland conservation strategy should consider the differences in species composition between vegetation types if the highest number of species is to be conserved.

Keywords: diameter class distribution, species diversity, stump characteristics

Introduction

Approximately 24% of Uganda's total land area is covered by forests, 80% of which are savanna woodlands (MWLE 2001, EMPAFORM 2008). Savanna woodlands in Uganda are facing considerable pressure from conversion to agricultural lands, charcoal burning and firewood collection (Hamilton 1984, van Orsdol 1986, Howard 1991, UNDP 2007). The high pressure on savanna woodlands has been attributed to the rapid human population increase and high dependence on woody biomass fuel for domestic cooking (MWLE 2001). It is estimated that 90% of Ugandans use wood as their main or only source of energy, consuming 16 million tonnes of firewood and 4 million tonnes of charcoal each year. Savanna woodlands have been targeted as a source of charcoal for urban centres because of the high calorific value of charcoal from savanna woodland tree species (MWLE 2002).

Maruzi Hills Forest Reserve, located in northern Uganda, is not only a source of charcoal but also firewood for fish smoking because of its proximity to fish landing sites. Anthropogenic disturbances have been identified as key factors in determining changes in vegetation structure, species diversity and composition of woodlands (Bond and van Wilgen 1996, Beaty and Taylor 2001, Hudak et al. 2004, Nangendo 2005). It is therefore important to conduct systematic evaluation of the ecological changes overtime in highly disturbed savanna woodlands. This will allow for the identification of specific conservation needs and provide information necessary for the development of sound integrated forest management systems. This study was therefore conducted to establish the composition, structure and utilisation patterns of woody perennials in Maruzi Hills Forest Reserve.

Materials and methods

Study area

Maruzi Hills Forest Reserve is a watershed protection woodland forest found in the Apac district of northern Uganda. It is located between 1°44′–1°47′ N and 32°18′–32°20′ E at an altitudinal range of 1 050–1 370 m above sea level. The forest is covered by the Uganda Department of Lands and Surveys map sheets 40/2 and 40/4 (series Y732) at 1:50,000 (Davenport and Howard 1996). The reserve was gazetted in 1939, but with subsequent realignments until 1967. It is currently managed by the National Forestry Authority (NFA). Although the forest is located in a relatively less-populated part of the country, the pressure on the forest for firewood, charcoal, poles and non-timber forest products has increased (Forest Department 2002). The vegetation can be described as dry combretum savanna

mainly composed of *Combretum–Terminalia–Loudetia*, *Combretum–Hyparrhenia* and *Acacia–Albizia–Panicum–Chloris* community types (Langdale-Brown et al. 1964). Accordingly, there are three main vegetation types in Maruzi Hills forest, namely, woodland, bushland and grassland (NFA 2008). Woodland vegetation was characterised by dense shrubs and trees with a grass understorey, while bushland vegetation had thickets of short thorny bushes between widely spaced shrubs and trees. Grassland vegetation had open grassland with widely spaced shrubs and trees.

Sampling

A reconnaissance survey was conducted between January and February 2009 to stratify the vegetation of the forest reserve for subsequent inventory. Stratified random sampling was used to site two (100 m × 100 m) permanent sample plots (PSPs) in each of the three vegetation types mentioned above (Figure 1). A grid map of Maruzi Hills woodland forest was used to randomly site plots within each vegetation type. Each 100 m × 100 m PSP was divided into four quadrats marked by T-trenches, while the corners were marked by L-trenches. In each plot, all woody plants with diameter at breast height (DBH) ≥5 cm were identified, labeled with chlorinated rubber paint, and their DBH and height were recorded. The trees were identified with the help of field identification keys in Eggeling and Dale (1951). Specimens of the species that were not immediately identified in the field were taken to the National Forestry Resources Research Institute for expert identification. The number of charcoal kilns (active and harvested) in each plot were recorded. The ground-level diameter, species and estimated age of the stumps (from harvested trees/shrubs) were also recorded. As shown in Table 1, stump age was determined by categorising all stumps into four age groups based on physical characteristics.

Statistical data analysis

Species diversity, richness and evenness of the three vegetation types in Maruzi Hills Forest Reserve were analysed by constructing Rényi diversity profiles using R software 2.6.1 (R Development Core Team 2005). The difference in species composition between the vegetation types was analysed using the Bray-Curtis and Jaccard ecological distance matrices, while species abundance was measured by a rank–abundance curve. Average stem density, basal area, DBH size-class frequencies and stump diameter size-class frequencies were enumerated. To facilitate data analysis, the DBH measurements were grouped into arbitrary classes of 5 cm intervals. Pearson correlation of number of charcoal kilns (active and harvested) to number of tree/shrub stumps in permanent sample plots was analysed. Chi-square (χ^2) test of association between vegetation type and tree diameter class was conducted. The harvesting trend was also analysed using frequency counts of stump age groups.

Results

Species abundance

Inventory of six (100 m × 100 m) PSPs enumerated 428 trees in the woodland vegetation comprising 32 species, 382 trees in the bushland vegetation comprising 16 species, and 229 trees in the grassland vegetation comprising 26 species. The species with the highest proportional abundance in the survey were *Combretum molle* (23%), *Acacia hockii* (17.7%), *Combretum collinum* (16.1%), *Grewia mollis* (6.5%) and *Lannea barteri* (6.5%) (Figure 2). The species with the highest proportional abundance in the woodland vegetation were *C. molle* (31.1%), *C. collinum* (20.8%) and *G. mollis* (13.1%), while the highest in the bushland vegetation were *A. hockii* (37.6%), *A. seyal* (11.4%) and *A. tortilis* (11.4%). The species with the highest proportional abundance in the grassland vegetation were *C. molle* (31.5%), *C. collinum* (16.2%) and *A. hockii* (12.2%).

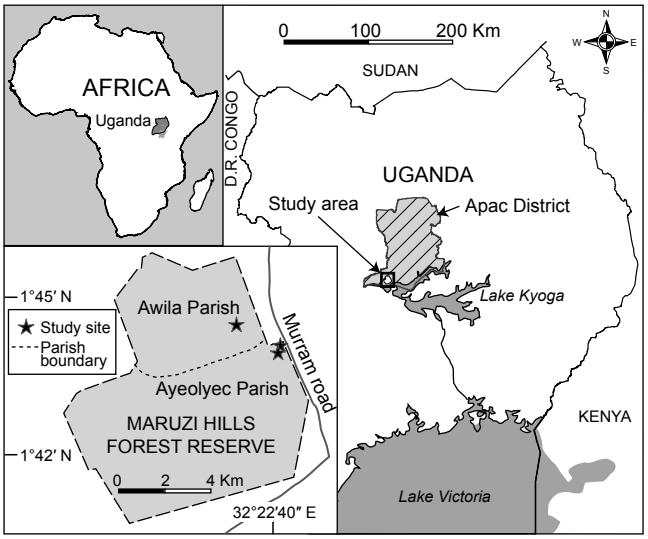

Figure 1: Location of the Maruzi Hills Forest Reserve

Table 1: Categorisation of stump age groups

Stump age group	Physical characteristics of stump
New stumps	Wet bark and/or coppice <1 m tall
Old stumps	Dry stump and/or coppice >1 – 2 m tall
Older stumps	Very dry and/or coppice >2 – 4 m
Oldest stumps	Rotting (disintegrating) stump or coppice >4 m

Ecological distance and diversity

The Bray-Curtis and Jaccard distance matrices (Table 2) showed that although the three vegetation types share some common species the ecological distance between vegetation types is relatively high, particularly between bushland vegetation and the other two vegetation types.

Rényi diversity profiles indicated that bushland vegetation had lower species diversity than grassland and woodland vegetation (Figure 3). However, grassland and woodland vegetation species diversity could not be ordered due to intersection of their profiles. According to Kindt and Coe (2005), ordering of species diversity is not possible in cases of intersecting Rényi profiles. Species richness was

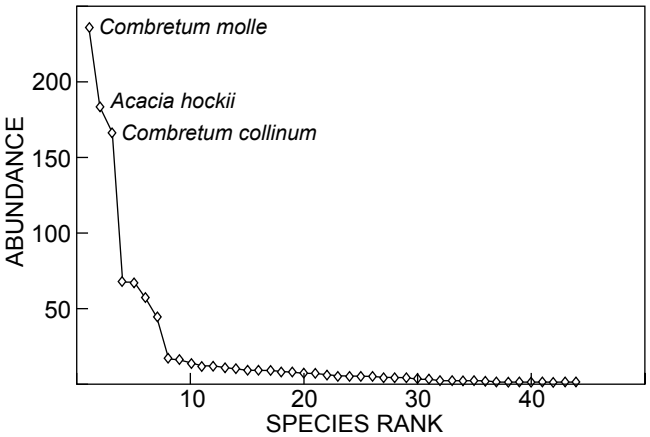

Figure 2: Rank–abundance curve of species in Maruzi Hills Forest Reserve

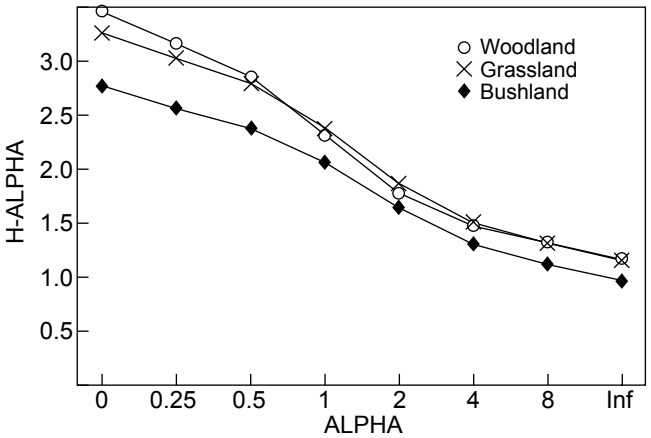

Figure 3: Rényi diversity profiles for the three vegetation types in Maruzi Hills Forest Reserve

Table 2: Bray-Curtis and Jaccard distance matrices. J = Jaccard distance, BC = Bray-Curtis distance

Vegetation type	Woodland	Bushland
Bushland	0.7982063 (J)	
	0.6641791 (BC)	
Grassland	0.6686992 (J)	0.7289916 (J)
	0.5022901 (BC)	0.5735537 (BC)

highest in the woodland vegetation ($\alpha_0 = 3.46$), followed by grassland ($\alpha_0 = 3.25$) and lowest in the bushland ($\alpha_0 = 2.77$). Grassland and woodland vegetation had lower proportions of the dominant species ($\alpha_\infty = 1.15$ and 1.66, respectively) than bushland vegetation plots ($\alpha_\infty = 3.25$).

Vegetation structure

The average basal area decreased from woodland vegetation (4.338 m^2 ha^{-1}) to grassland (1.659 m^2 ha^{-1}) and was lowest in bushland (1.472 m^2 ha^{-1}) (Table 3). The mean stem density of the woodland, bushland and grassland vegetation was 214 stems ha^{-1}, 191 stems ha^{-1} and 114 stems ha^{-1}, respectively. Diameter size classes (5–10 cm) and (10.1–15 cm) accounted for 81% of total stem counts, while 28 trees (2.6%) had DBH over 30 cm. The remaining 16.4% had DBH between 15.1 and 30 cm. The χ^2 test indicated significant association between vegetation type and tree diameter class (p-value < 0.001). The bushland vegetation had a higher percentage of trees with smaller diameter classes (5–15 cm; Table 3) than the other two vegetation types.

Frequency distribution of diameter size classes indicated that 62.2% of stumps had diameter at ground level below 15 cm, while only 13% were more than 25 cm (Table 4). The species with highest stump counts included *C. collinum* (35.9%), *C. molle* (31.3%) and *A. hockii* (15.2%).

Pearson correlation of number of charcoal kilns (active and harvested) to number of tree/shrub stumps in permanent sample plots was strongly positive (0.877; $p < 0.022$). Frequency counts of stump age groups indicated that the harvesting pressure had decreased in recent times (Figure 4).

Discussion

Some of the most abundant species in the forest reserve (*Combretum molle*, *C. collinum* and *Lannea barteri*) are known to be fire resistant **(**Katende et al. 1995), characteristic of trees that achieve maximum abundance in areas of frequent fires. This indicates that fire could have influenced the species composition in Maruzi Hills woodland forest. It was observed during data collection that local people regularly use fire as a management tool for refreshing grass for domestic animals, hunting and land clearing. Fire, mostly of anthropogenic origin, has been singled out as a key element in determining vegetation structure and species composition of savannah woodlands (Hudak et al. 2004).

Although eight species occurred in all the vegetation types and 12 species occurred in at least two vegetation types, the Bray-Curtis and Jaccard ecological distance matrices (Table 2) were relatively high suggesting significant species composition variation between the three vegetation types, particularly between bushland vegetation and the other two vegetation types. The Bray-Curtis distance can be influenced by species with the largest differences in abundance, while the Jaccard distance depends on presence-absence of values (Kindt and Coe 2005). Since the Bray-Curtis and Jaccard distances show the same pattern, it implies that the influence of species with largest difference in abundance is minimal. Bushland vegetation had the highest distance from the other two vegetation types due to lower species richness (Figure 3) and much higher proportional abundance of *Acacia* species. This may be attributed to selective extraction of particular species that are preferred for charcoal, firewood and other domestic uses. Analysis of harvesting trends (Figure 4) also indicated more new stumps in the bushland vegetation than the other two vegetation types. Probably, more effort should be directed towards conservation of the woodland vegetation, which has higher species diversity. Several studies have indicated that factors ranging from parent rock qualities, soil water-holding capacity, topography and fire may influence differences in species composition (Corney

Table 3: Mean stem density, average basal area and diameter class distribution of woody perennials ≥5 cm

Vegetation type	Mean stem density (stems ha^{-1})	Average basal area (m^2 ha^{-1})	Diameter class (cm)					
			5–10	10.1–15	15.1–20	20.1–25	25.1–30	>30
Woodland	214	4.338	220	103	46	23	13	23
Grassland	114	1.659	128	42	32	17	7	3
Bushland	191	1.472	309	44	17	7	4	1
Total			657	189	95	47	24	27

Table 4: Stump species and diameter size class distribution

Vegetation type	No. of stumps	Most harvested spp	Stump diameter class (cm)					
			<10	10.1–15	15.1–20	20.1–25	25.1–30	>30
Woodland	89	*C. collinum* *C. molle*	13	12	22	18	9	15
Bushland	67	*C. collinum* *A. hockii*	39	19	4	2	0	3
Grassland	61	*C. collinum* *A. hockii* *C. molle*	41	11	7	0	2	0



Figure 4: Harvesting trend in Maruzi Hills Forest Reserve

et al. 2004, Swaine et al. 1992, Jones 1992). Therefore, a study on the environmental and socioeconomic factors that have contributed to the species composition in Maruzi Hills Forest Reserve should be undertaken to provide information necessary for designing species conservation strategies.

Stump records indicated that small woody perennials were most harvested (Table 4), probably because they were the most abundant (Table 3). However, removal of small-sized trees is also indicative of firewood harvesting. One common characteristic of the most harvested species (Table 4) is their high calorific value, which could have made them highly valued for charcoal and firewood. This suggests that charcoal burning and firewood collection were among the main causes of harvesting. This is further supported by the strong positive linear relationship between number of charcoal kilns (active and harvested) and number of tree/shrub stumps in permanent sample plots.

Given the low stem density and basal area per hectare in the forest reserve (Table 3), the rate of harvesting should be controlled to ensure sustainable management of the forest reserve. Since all of the most harvested species can be managed by coppicing and pollarding (Katende et al. 1995), these techniques should also be taught to the forest adjacent communities to reduce rate of resource depletion. Unfortunately, the fact that these species are slow growing makes them unsuitable for use by individual farmers either for plantation development or for agroforestry, leaving *in situ* conservation and planting by the NFA as the most viable options. Fortunately, stump records indicated a recent decrease in rate of tree/shrub harvesting (Figure 4), which NFA staff attributed to increased forest patrols.

Conclusion

The significant species composition variation between the three vegetation types suggests that Maruzi Hills woodland forest conservation strategy should consider the difference in species composition between vegetation types if the highest number of species is to be conserved. The association between vegetation type and tree diameter classes, particularly the higher percentage of bushland vegetation trees in the smaller diameter classes than the other vegetation types, requires further investigation. The environmental and socioeconomic factors that have contributed to the species composition in Maruzi Hills Forest Reserve should be understood to provide information necessary for designing species conservation strategies. *In situ* conservation of threatened species should be complemented with planting by the National Forestry Authority.

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