Diversity and composition of trees and shrubs in Kasagala forest: a semiarid savannah woodland in central Uganda

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Abstract

The diversity and composition of trees and shrubs of ≥5 cm diameter at breast height (DBH) were investigated in Kasagala woodland in central Uganda using 1 ha permanent sample plots. A total of 2745 trees and shrubs with a mean stem density of 686 ha^{-1} were recorded. These included 69 tree species belonging to 28 families and 47 genera. There was a larger number of small stems compared with that of larger stems. There was significant variation in stem size class distribution between the plots ($F = 3.14$, $P = 0.027$). The variation in stem densities (counts) across different size classes was significant ($F = 8.31$, $P < 0.001$). Species diversity was higher in the low lands compared with that in the elevated sites in the woodland. The species encountered were unevenly distributed across the plots. Species abundance was not significantly different across the sample plots ($F = 2.63$, $P = 0.053$). We suggest that the structure of the forest is typical of any regenerating forest, but other human influences may have played a part in the dominance of size classes <10 cm DBH. The causes of the present status and composition of the woodland require further investigation.

Key words: Detrended Correspondence Analysis, Kasagala, permanent sample plots, Rényi profiles, savannah woodlands, species diversity

Résumé

La diversité et la composition des arbres et arbustes de plus de 5 cm dbh ont été étudiées dans la forêt de Kasagala, au centre de l'Ouganda, en utilisant des parcelles échantillons permanentes d'un hectare. On a relevé la présence de 2745 arbres et arbustes, avec une densité moyenne de 686 troncs ha^{-1}. Ceux-ci comprenaient 69 espèces d'arbres appartenant à 28 familles et à 47 genres. Il y avait un plus grand nombre de petits troncs que de gros. Il y avait une variation significative de la distribution des classes de taille entre les parcelles ($F = 3.14$, $P = 0.027$). La variation de la densité des troncs (comptages) entre les différentes classes de taille était significative ($F = 8.31$, $P < 0.001$). La diversité des espèces était plus grande dans les terres basses que dans les sites plus élevés dans la forêt. Les espèces rencontrées étaient distribuées de façon inégale entre les parcelles. L'abondance des espèces n'était pas significativement différente selon les parcelles échantillons ($F = 2.63$, $P = 0.053$). Nous suggérons que la structure de la forêt est typique de toute forêt en voie de régénération, mais que d'autres influences humaines peuvent avoir joué un rôle dans la dominance des classes de taille <10 cm dbh. Les raisons du statut et de la composition actuels de la forêt requièrent de nouvelles investigations.

Introduction

The composition and diversity of plant species in woodlands are management issues of great concern today because of their conversion for agricultural uses. Composition and structure of woodlands are also greatly influenced by environmental and anthropogenic factors (Belsky, 1984; Pellew, 1983; Ruess & Halter, 1990; Walpole, Nabaala & Matankory, 2004). In Uganda, 81% of the 4.9 million ha of forest cover is woodland, most of which is found in the semiarid areas of the country (Kayanja & Byarugaba, 2001; Ministry Of Lands, Water & Environment (MWLE), 2001). Uganda's woodlands are extremely degraded and continue to decline due to a combination of drought, agricultural expansion, population pressure and overexploitation (Okorio *et al.*, 2004). Within the last 10 years, a growing middle class has mounted pressure on woodland ecosystems by establishing large-scale cattle ranching accompanied by extensive

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cutting of trees to release the growth of pasture grass. The conversion of woodland ecosystems to agricultural land is likely to cause large-scale impacts on the hydrology, soils and general climate unless the dynamics are fully understood and mitigation measures are designed.

Savannah woodland dynamics have been widely studied throughout eastern Africa (Belsky, 1984; Pellew, 1983; Ruess & Halter, 1990). These studies show that fire, grazing, browsing and trampling have hampered regeneration in woodland vegetation in the Serengeti National Park in Tanzania. Studies on the ecological dynamics of savannah woodlands in Uganda have shown that even in the absence of fire, animal pressure can impact on woodland dynamics (Buechner & Dawkins, 1961; Laws, Parker & Johnstone, 1975). Woodland recovery has been associated with decreasing intensities of browser pressure (Lock, 1993; Smart, Hatton & Spence, 1985). Long-term studies of the woodlands should therefore provide information upon which recovery options and management decisions can be based (Nangendo, 2005; Namaalwa, Eid & Sankhayan, 2005; Vanclay, 1992). Little quantitative information exists on the structure and composition of Uganda's woodlands. Woodlands are not accorded as much importance as tropical rain forests unless they are protected as National Parks. To get a better understanding of the diversity and dynamics of woodlands, it is important to generate data sets that are truly representative of such woodlands. In this study, we addressed the hypothesis that species diversity is uniform and evenly distributed in Kasagala woodland forest. The aim of this study, therefore, was to conduct a rapid assessment of the tree and shrub species in Kasagala woodland forest. The emphasis was to evaluate the species composition and diversity to guide management and policy decisions. We established permanent sample plots (PSP) for long-term observation of woodland forest dynamics and for informing management and policy decisions regarding woodlands in Uganda.

Materials and methods

Study area

Kasagala forest reserve is located between 0°55′ and 1°33′N, and 32°00′ and 32°35′E in Buruli county of the Nakasongola district of Uganda (Fig. 1). The reserve covers an area of 103 km^2 with an altitudinal range of 1057–1160 m asl. The highest point of the forest is the Kasagala hill outcrop.

The average annual temperature is 28°C and average annual rainfall ranges from 875 to 1000 mm (Kaaya & Kyamuhangire, 2006). The area lies in the Acholi–Kyoga climatic zone of Uganda and receives mainly convectional

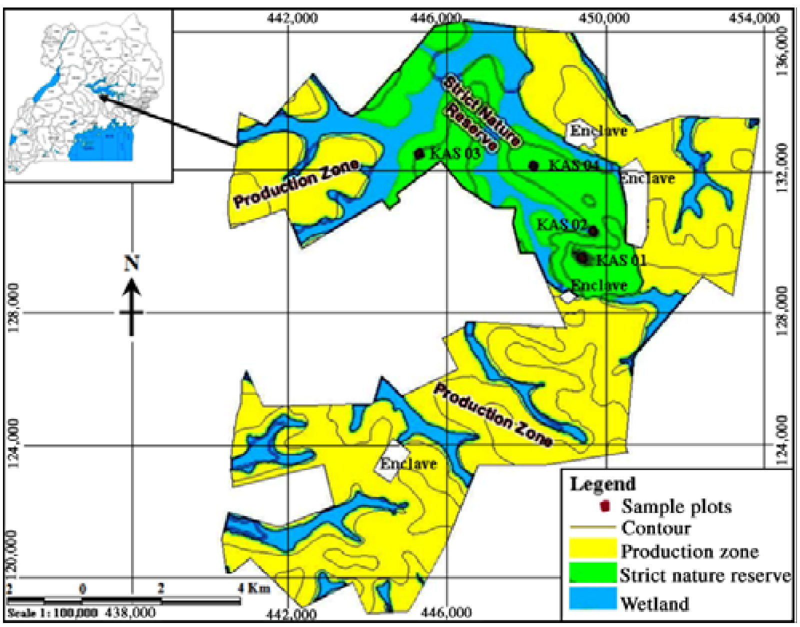

Fig 1 Map of Kasagala central forest reserve showing its location in Uganda

rainfall characterized by afternoon and evening occurrences [National Environment Management Authority (NEMA) NEMA, 2005]. It lies on the Tanganyika pedeplain composed of the Buruli catena and Lwampanga series. The soils are generally ferrallitic, mainly made up of sandy and non-differentiated loams (Uganda Department of Lands & Surveys, 1959).

Kasagala woodland was gazetted as a forest reserve in 1968 and placed under the administration of the Uganda Forest Department. As a savannah woodland reserve, it was set aside as a catchment forest for Lake Kyoga and for biodiversity conservation [National Forestry Authority (NFA) NFA, 2005]. Between 1993 and 1995, the Uganda Forest Department conducted extensive biodiversity surveys of the forest reserves of Uganda (Howard & Davenport, 1996). Following this, the woodland was zoned into a production zone and a strict nature reserve (SNR) (MWLE, 1999) (Fig. 1). The SNR covers an area of 21 km^2, including the Kasagala hill. The production zone was allocated by the National Forestry Authority (NFA) to private commercial tree farmers (under a permit system) to establish plantations of mainly *Pinus caribaea* Morelet and *P. oocarpa* Schiede ex Schltdl. for saw logs. Four enclaves (human habitations that existed prior to the creation of the forest reserve) are also located within the boundaries of the reserve (Fig. 1).

The vegetation of the woodland lies within the Lake Victoria Regional Mosaic (White, 1983). Langdale–Brown, Osmaston & Wilson (1964) described the vegetation of the woodland as 92% *Combretum–Terminalia–Loudetia* savannah with only 8% covered by *Sorghastrum* grassland. A previous inventory of Kasagala forest (Davenport, Howard & Baltzer, 1996) identified a total of 164 species of trees and shrubs, 119 species of birds, 21 species of small mammals (7 shrews and 14 rodents), 76 species of butterflies and 39 species of moth (27 hawkmoth and 12 silkmoth). Two restricted-range plant species, *Vernonia iodocalyx* O. Hoffm. and *Viscum bagshawei* Rendle, were also recorded from this forest. Among the mammals, *Tatera leucogaster* Peters (Savannah Woodland Gerbil), a new addition to the Ugandan mammal list, was recorded. The woodland therefore has a very important biodiversity value.

This study was conducted within the SNR where the vegetation is representative of the entire forest reserve. We classified the vegetation into four categories of vegetation types:

1 Dry woodland with thickets and scattered trees on Kasagala hill dominated by *Mystroxylon aethiopicum* (Thunb.) Loes, *Hymenocardia acida* Tul., *Combretum collinum* Fresen and *Strychnos innocua* Delile.

2 Lowland woodland with seasonal wetland (flooded seasonally).

3 Dry woodland and thicket dominated by *Euphorbia candelabrum* Tremaut ex Kotschy.

4 Dry woodland dominated by *C. collinum.*

Tree and shrub inventory

One PSP measuring 100 × 100 m was established in each of the four vegetation types, giving a sampling intensity of 0.08% (adapted from Alder & Synnott, 1992). The plots were oriented to the magnetic north–east direction and sequentially numbered preceded with the code KAS (short for Kasagala). A Garmin 12XL Global Positioning System was used to take readings of the approximate locations of each of the corner points for the plots. The plot corners were clearly marked with concrete 1 m × 1 ml – shaped cairns reinforced with metal studs. Additional concrete cairns were located at 50 m at the midpoint of every 100 m stretch of the plot boundaries. The use of concrete cairns to mark the PSP boundaries was necessitated by the high incidences of cattle grazing that would easily obliterate the trenches and soil mounds, which are the traditional methods for demarcating PSPs in forest reserves.

Diameter measurements were taken for all trees/shrubs ≥5 cm at breast height using a diameter tape. Trees/shrubs were measured systematically in a clockwise direction for each PSP. For multi-stemmed individuals, each stem with a diameter at breast height (DBH) ≥5 cm was considered as an individual. All the trees measured for DBH were identified in the field. Extensive use was also made of relevant field identification guides and taxonomic literature, including Eggeling (1951), Beentje (1994), Blundell (1987), Heywood (1993) and Mabberley (1997).

Manipulation and statistical analysis of data

The following values were calculated for all the trees/species encountered:

Relative frequency (Rf): number of plots in which a species occurs divided by the total number of occurrences of all species in all the plots ×100.

Relative density (Rd): number of individuals of a species divided by the total number of individuals of all species×100.

Basal area (BA):

$$\pi d^2/4\ (10,000) \text{ or } 0.0000786d^2$$

where π is the constant 3.147, d is the diameter at breast height in cm^2. DBH was measured in centimetres, hence the conversion factor of 10,000 was used to calculate the basal area.

Relative dominance (RD): the BA of a species divided by the sum of BA of all species ×100.

Importance value (IV): Rf + Rd + RD, where Rf is relative frequency, Rd is relative density and RD is relative dominance.

DBH measurements were grouped into 14 size classes, with a class interval of 5 cm. Species abundance and distribution between the different sample plots and size classes were compared using one-way analysis of variance (ANOVA) in Minitab for Windows version 12.22 (Minitab Inc., State College, PA, USA), employing species frequencies and log transformed mean DBH values for each species. Species richness, diversity, evenness and influence of dominant species in the sample plots were obtained by constructing Rényi profiles at 100 permutations for the four sample plots using the R statistics software version 2.6.1 (R Development Core Team, 2007). The stem density of the species in each sample plot was used to construct the Rényi diversity and evenness profiles. To assess β diversity, a Detrended Correspondence Analysis (DCA) (Hill & Gauch, 1980) was performed based on Bray–Curtis distances using the R statistics software version 2.6.1 (R Development Core Team, 2007). DCA uses data on species composition and abundance to classify samples or plots (Walpole *et al.*, 2004).

Results

Species composition

A total of 2745 trees and shrubs ≥5 cm DBH with a mean stem density of 686 ha^{-1} belonging to 69 tree species were recorded. These belonged to 28 families and 47 genera. The largest families with more than ten species each and common to all the PSPs were Moraceae (11 species) and Fabaceae (10 species). Other families were Euphorbiaceae (5 species), Anacardiaceae (4 species), Meliaceae (4 species) and Celastraceae (3 species). Combretaceae, Ebenaceae, Flacourtiaceae, Rhamnaceae, Rubiaceae, Rutaceae, Sapindaceae, Tiliaceae and Verbenaceae had two species each recorded. The rest of the families had one species each.

Kasagala hill where plot 1 (KAS 1) was located had the highest stem density of 1459 stems ha^{-1} comprising 37 species, while plot 3 (KAS 3) had the lowest stem density (330 stems ha^{-1}) comprising 35 species. Plot 2 (KAS 2) had a density of 501 stems ha^{-1} consisting of 41 species while plot 4 (KAS 4) had a stem density of 455 stems ha^{-1} consisting of 33 species. Analysis of variance showed that there was no significant difference in species abundance between the sample plots ($F = 2.63$, $P = 0.053$).

Seven species accounted for over 60% of the stem density of the woodland: *M. aethiopicum*, *C. collinum*, *Rhus natalensis* Bernh. Ex Krauss, *H. acida*, *S. innocua*, *Vitex fischeri* Gürke and *Vepris nobilis* (Delile) W. Mziray. While *C. collinum* occurs and is spread over all the four sample plots, *M. aethiopicum* was found to aggregate in thickets and elevated sites in plots 1 (KAS 1) and 2 (KAS 2), and was absent in plots 3 (KAS 3) and 4 (KAS 4). Half of the species encountered had <10 individuals. Ten species recorded during the inventory were singletons. *Antiaris toxicaria* Lesch. and *E. candelabrum* were the most evenly dispersed over all the different size classes, followed by *C. collinum* and *M. aethiopicum*. The relative density, relative dominance, relative frequency, BA and importance value of ten species with the highest importance values are shown in Table 1.

The trend in diameter frequency distribution for the four most abundant species is shown in Fig. 2. Over 90% of the total stems encountered were <50 cm DBH. Only ten trees had a stem diameter >40 cm, representing 0.4% of the total stem count. These were *E. candelabrum*, *A. toxicaria*, *A. coriaria*, *F. ovata* and *Ziziphus abyssinica* Hochst. ex A. Rich. We found a significant difference in stem density across the different size classes ($F = 8.31$, $P < 0.001$). *Mystroxylon aethiopicum* was the most abundant species in four of the six size classes <40 cm DBH, while *C. collinum* was the most abundant in one size class (20–25 cm) (Fig. 2). There was significant variation in mean DBH between the plots ($F = 3.14$, $P = 0.027$).

Tree species diversity and evenness

A combination of the different aspects of species diversity given by Rényi profiles for the four sample plots is shown in Fig. 3. In terms of species richness, plot 2 (KAS 2) was the most rich ($H_\alpha = 3.71$), followed by plot 1 (KAS 1) ($H_\alpha = 3.60$). Plot 4 (KAS 4) was the least species rich ($H_\alpha = 3.50$), while plot 3 (KAS 3) had a species richness of $H_\alpha = 3.56$ (Fig 3). The profile for plot 2 (KAS 2) in Fig. 3

Table 1 Stem counts, basal areas, relative dominance, relative densities and relative frequencies of ten species with the highest importance value

Species	Family	SC	BA	RD	Rd	Rf	Iv
1. *Mystroxylon aethiopicum*	Celastraceae	580	5.78	17.89	21.13	1.37	40.39
2. *Antiaris toxicaria*	Moraceae	80	7.38	22.87	2.91	2.05	27.84
3. *Combretum collinum*	Combretaceae	275	2.85	8.82	10.02	2.74	21.58
4. *Rhus natalensis*	Anacardiaceae	256	1.15	3.58	9.33	2.74	15.64
5. *Hymenocardia acida*	Euphorbiaceae	190	1.59	4.91	6.92	2.05	13.89
6. *Euphorbia candelabrum*	Euphorbiaceae	98	2.32	7.18	3.57	2.05	12.81
7. *Strychnos innocua*	Loganiaceae	139	0.89	2.76	5.06	2.74	10.56
8. *Vitex fischeri*	Verbenaceae	132	1.15	3.55	4.81	2.05	10.41
9. *Lannea kerstingii*	Anacardiaceae	86	1.31	4.04	3.13	2.74	9.92
10. *Vepris nobilis*	Rutaceae	129	0.68	2.11	4.70	2.74	9.54

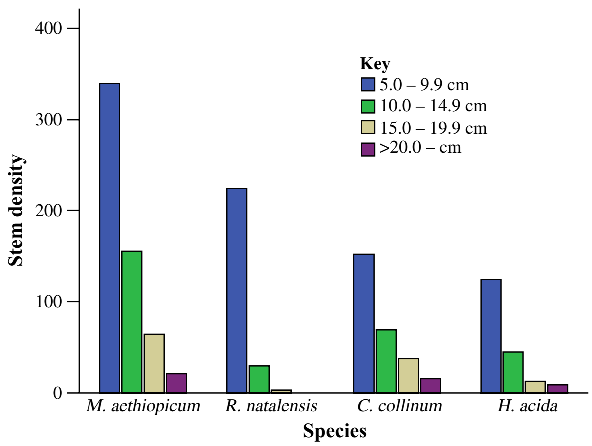

Fig 2 DBH-size class distribution of four (4) tree species with the highest relative density. Size classes are indicated on the bars in the chart

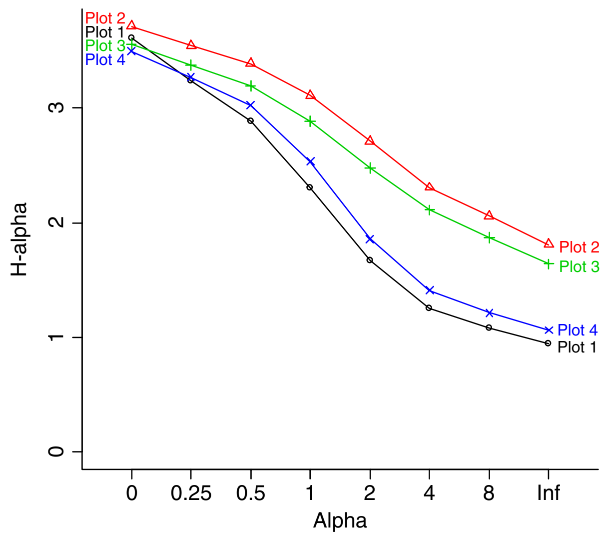

Fig 3 Rényi diversity profiles for the four (4) sample plots established in Kasagala woodland

indicates that this plot is the most diverse of the four sample plots. The Shannon diversity index ($\alpha = 2$ in Fig. 3) for plot 2 ($H_\alpha = 3.113$) is higher than that of the rest of the plots. A comparison of the species diversity of plot 1 (KAS 1) with that of plots 3 and 4 is rendered difficult by the intersection in their profiles (Fig. 3). Intersecting Rényi diversity profiles indicate cases where ordering of species diversity cannot be carried out (Kindt & Coe, 2005). However, the diversity of plot 3 (KAS 3) was higher than that of plot 4 (KAS 4) (Fig. 3).

All the sample plots did not have perfectly even species distribution (Fig. 3). The shape of the diversity profile is an indication of the evenness of species distribution in the plot. A horizontal profile indicates that all species have the same evenness (Kindt, *et al.*, 2006). The less horizontal a profile is, the less evenly distributed species are. From Fig. 3, it is evident that there is high influence from dominant species in each of the plots. Plot 1 (KAS 1) had the highest proportion of most dominant species ($\alpha_\infty = 0.95$), while plot 2 (KAS 2) had the least proportion of dominant species ($\alpha_\infty = 1.81$). Plot 3 (KAS 3) had a lesser proportion of dominant species ($\alpha_\infty = 1.64$) than plot 4 (KAS 4) ($\alpha_\infty = 1.06$).

The Detrended Correspondence Analysis (DCA) ordination diagram (Fig. 4), which is an Eigen analysis, shows that there was no considerable difference in species composition between the plots. The sample plots nevertheless had larger separations along the first than the second DCA axis. The first axis accounted for 53% of the total variation in species composition, while the second axis accounted for

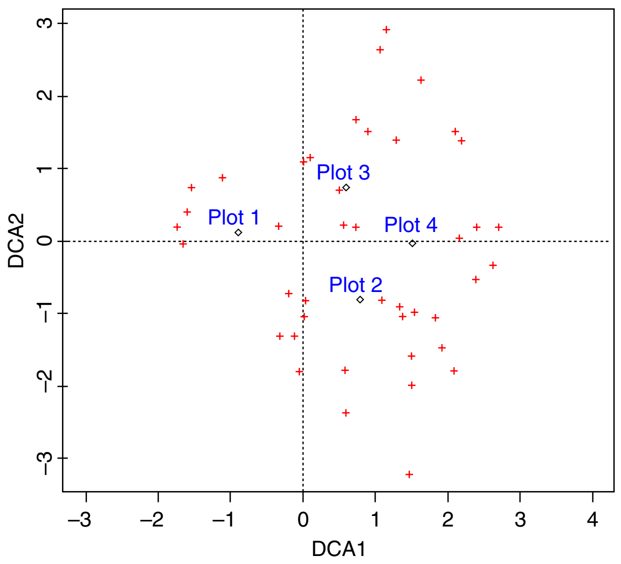

Fig 4 Detrended Correspondence Analysis (DCA) ordination diagram of the four (4) sample plots in Kasagala woodland. The symbols (+) represent species distribution in relation to the four (4) sample plots.

21%. Plot 1 was negatively correlated with plots 2, 3 and 4 along the first axis, while plots 2 and 4 were negatively correlated with plots 1 and 3 along the second axis (Fig 4). Plots 2 and 4 are more closely related in terms of species composition, while plot 1 is more distantly related to the other three plots.

Discussion

There is growing concern about the future structure and species composition of the woodlands given the potential of bio-energy production from these forests (MWLE, 2001). Uganda's woodlands are generally open access areas and provide most of the charcoal and firewood used in the urban centres (NEMA, 2005; Sankhayan & Hofstad, 2000). Kasagala woodland is geographically located near the major urban centres of Uganda and has therefore been a source of charcoal and firewood. Although this study did not collect data on species selection for charcoal and firewood, the most preferred species for valuable charcoal and firewood include *Combretum* spp., *Hymenocardia* spp., *Acacia* spp. and *Albania* spp. (Kalumiana & Kisakye, 2001).

Kasagala woodland is important for its biodiversity and ecological functions (NFA, 2005), but does not have unique floristic richness. A few species that have been described as restricted-range endemics have been recorded in this woodland (Davenport *et al.*, 1996). The presence of high numbers of smaller compared with larger trees is usually interpreted as an indicator of vibrant recruitment (Condit *et al.*, 1998; Wright *et al.*, 2003) and hence a balance between recruitment and mortality of individual species (Oliver & Larson, 1990). Although we did not collect data on tree/shrub harvesting during this study, we suggest that this could be one of the causes for the absence of larger size classes for many of the species encountered. However, savannah woodland tree and shrub species generally have small-sized stems. The presence of high numbers of smaller trees/shrubs agreed with our prior expectations. *Antiaris toxicaria* and *E. candelabrum* that had large stems over 50 cm DBH are not considered very valuable for the most common uses of firewood, charcoal and building and we suggest that this could be the reason these species are available with relatively larger stems. *Combretum* spp., which were recorded by Langdale–Brown *et al.* (1964), as dominant have been shown to be dominant in one size class and plot only (Fig. 2). We suggest that this may be due to local harvesting selection pressures. Obiri, Lawes & Mukolwe (2002) showed that removal of small pole-sized stems for subsistence use in small forest patches in South Africa resulted in the local extinction of some species. It is common in Africa, especially in forests which are easily accessible, to encounter removal intensities as high as 50% for small size classes (Hall & Rodgers, 1986). Human disturbance was found to be strongly correlated to the high number of small-sized trees in the Arabuko–Sokoke forest in Kenya (Oyugi, Brown & Whelan, 2007).

Species diversity and abundance in Kasagala forest vary between the four vegetation types sampled in this study. The high stem density in plot 1 could be due to the rough and rocky terrain giving rise to domination by the more competitive species *M. aethiopicum* and *H. acida*. With no or little disturbance, competitive species slowly dominate such a vegetation type (Connell, 1978; Huston, 1979). *Mystroxylon aethiopicum*, therefore, seems to be a case of an aggressive competitor that is dominant in plot 1 and is present in the nearest plot 2. Meanwhile, species diversity and abundance are much higher in plots 2 and 4, but lower in plot 3 possibly due to ease of access. Plots 2 and 4 are located almost in the middle of the forest, while plot 3 is nearer to the forest boundary. Plot 1 (rocky hill outcrop woodland vegetation) is negatively correlated to the other three plots which are lowland vegetation (Fig. 4). This is plausible given the locations and elevation of plot 1 on the one hand, and the species abundances of the remaining three plots on the other.

Kasagala forest reserve, previously classified by Langdale–Brown *et al.* (1964) as a *Combretum* dominated forest, is currently dominated by a few, unevenly distributed typical savannah woodland species: *M. aethiopicum*, *A. toxicaria*, *C. collinum*, *R. natalensis*, *H. acida* and *E. candelabrum*. As expected, the stem size distribution shows a large number of smaller stems compared with that of larger ones, owing to the small size of savannah tree/shrub stems. The low abundance of medium-sized and mature stems (30–50 cm DBH) of some of the species encountered requires further investigation. Management efforts should aim at maintaining a balanced size class distribution to ensure self-sustainability of the forest. Continuous monitoring is imperative to document and forestall any detrimental changes that will occur in this forest over the years. It is also important that this study is replicated in all the woodlands in the country, especially given the level of exploitation that these forests are faced with. There should be regular assessment of the PSPs established during this study to provide data and analyses to guide management and policy decisions for the semiarid savannah woodlands.

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