Taxonomic diversity, distinctness, and abundance of tree and shrub species in Kasagala Forest reserve in Uganda: implications for management and conservation policy decisions

Authors: Gwali, Samson, Okullo, Paul, Hafashimana, David, and Byabashaija, Denis Mujuni

Source: Tropical Conservation Science, 3(3) : 319-333

Published By: SAGE Publishing

URL: https://doi.org/10.1177/194008291000300306

Research Article

Taxonomic diversity, distinctness, and abundance of tree and shrub species in Kasagala forest reserve in Uganda: implications for management and conservation policy decisions

Samson Gwali[a,†], Paul Okullo[a,*], David Hafashimana[a,§] and Denis Mujuni Byabashaija[a,‡]

[a] National Forestry Resources Research Institute, Kampala, Uganda. **E-mails:** † gwalis@yahoo.co.uk; paul.okullo@yahoo.com; § davidhaf2000@yahoo.com; ‡ dbmujuni@yahoo.com

Corresponding author: Samson Gwali [gwalis@yahoo.co.uk]

Abstract

The successful management of natural resources requires access to adequate information on social, economic, ecological, and cultural changes in order to mitigate their impacts through conservation interventions. In most cases, such information is provided in the form of simple diversity indices, which may not predict the complex nature of species functioning in ecosystems. In this study, we used rank abundance, analysis of similarities (ANOSIM), similarity percentages (SIMPER), and taxonomic-diversity and distinctness indices to show the status of tree and shrub species in Kasagala forest reserve in central Uganda. Four 100 × 100 m plots were established in four vegetation strata of the strict nature reserve of the forest, and diameter at breast height (DBH) of trees and shrubs ≥ 5 cm measured. There was no significant difference in species abundance in the four vegetation strata (Kruskal Wallis H = 2.614, $p = 0.453$; ANOSIM: R = -0.334, $p = 0.995$). The taxonomic diversity and distinctness of the four vegetation types ranged between 2.414 and 2.786 while the taxonomic distinctness values ranged between 2.897 and 2.978. The taxonomic diversity of the forest is generally even, suggesting a homogeneous community. We suggest that the managers of the forest constitute a continuous monitoring program aimed at controlling the impact of anthropogenic factors, one of the main influences for such low taxonomic distinctness values observed for this forest.

Keywords: Kasagala, diversity, distinctness, abundance, ANOSIM, SIMPER, conservation policy

Received: 1 July 2010; Accepted: 28 August 2010; Published: 27 September 2010

Cite this paper as: Gwali, S., Okullo, P., Hafashimana, D. and Byabashaija, D. M. 2010. Taxonomic diversity, distinctness, and abundance of tree and shrub species in Kasagala forest reserve in Uganda: Implications for management and conservation policy decisions. *Tropical Conservation Science* Vol. 3 (3):319-333. Available online: www.tropicalconservationscience.org

Introduction

Forest ecosystems provide numerous ecological services and economic benefits to many national economies in the world [1, 2]. Currently, there is growing concern about the depletion of the world's forests [3-6]. However, conservation for ecological services such as climate amelioration, pollution control, and buffer zone protection is seldom perceived in terms of economic benefits [7-9]. For many people and economic planning authorities, forest ecosystems should meet immediate needs of mankind such as employment, food, and shelter. Therefore, conservation for ecological services is usually placed in the second pecking order of action. It is not surprising that industrial development leads to large-scale clearance of forested or wooded areas [6]. In most cases, ecosystem conservation value is not computed. Where it is done and all conservation services are properly costed, the importance of forest ecosystems is often more immense than alternative land use options such as industrialization [8-11].

Successful natural resource management and conservation are usually hindered by lack of or inadequate information to guide decision-making [8, 12]. Since changes in vegetation usually manifest themselves in social, economic, ecological, and cultural impacts [13], there is a need to monitor vegetation and land-use changes in order to mitigate their impacts through conservation interventions. In most cases where information on vegetation structure is provided, simple diversity indices are used to characterize the biodiversity of ecosystems. However, biodiversity is much more complex and is not just the abundance of species in an area, since not all species contribute equally to the functioning of ecosystems [14, 15]. Therefore, simple estimates of species diversity such as abundance, richness, and evenness remain only crude estimations of community structure [16]. The effect of environmental perturbations to an ecosystem can be better understood only if a suitable estimate is made that utilizes the effect of such perturbations to assess related individuals in the ecosystem.

Clarke and Warwick [17] pioneered a method of measuring taxonomic distinctness and taxonomic diversity that is sensitive to community perturbation and is therefore appropriate to detect differences among communities. Taxonomic diversity is the average (weighted) path length between every pair of individual organisms, with individuals in the same genus being closer than individuals in the same family [17]. On the other hand, taxonomic distinctness has been defined as the average (weighted) path length between every pair of individuals, ignoring the paths between individuals of the same species [17]. Therefore, while taxonomic diversity deals with the relatedness of individuals in the same genus, family, or order, taxonomic distinctness quantifies the relationship of individuals in a sample [15], thereby utilizing community structure as a whole. These two measures of diversity are therefore able to measure the diversity of an ecosystem, taking into consideration the disappearance of related and unrelated organisms and thus making conservation and management decision-making more tenable.

Whereas taxonomic diversity and distinctness indices have been widely used in marine studies, they are gaining popularity in the measurement of the conservation value of vegetation communities [18, 19]. In Uganda, where the country's woodland are facing severe pressure from exploitation for charcoal, timber, and poles, these indices can be very useful in assessing the present conservation status of such woodlands. Kasagala forest in Uganda is a typical example of an important vegetation pocket that is facing severe wood extraction for the provision of charcoal and firewood due to its proximity to Uganda's major urban centers. This situation is exacerbated by the steep growth in human populations and a corresponding demand for agricultural land, which has reduced the buffer zone area of the forest.

Previously set aside to provide ecosystem services and offer catchment protection to Lake Kyoga, an inland water body that is gradually drying up due to loss of surrounding vegetation cover [20], this forest is of immense ecological value. Moreover, with a record of high stocks of *Combretum* trees and the serious threat posed by forest clearance (Figure 1b), this woodland is specifically vulnerable, since *Combretum* firewood and charcoal are highly preferred by the urban markets of Uganda [21]. Moreover, encroachers are quick to turn parts of the forest into agricultural land, so that only those areas with more difficult terrain retain a reasonable number of larger-stemmed tree individuals (Fig. 1). In view of the above, a study was carried out to investigate the taxonomic diversity and distinctness of the tree species in the forest so as to make conservation and policy recommendations regarding the future management of the forest.

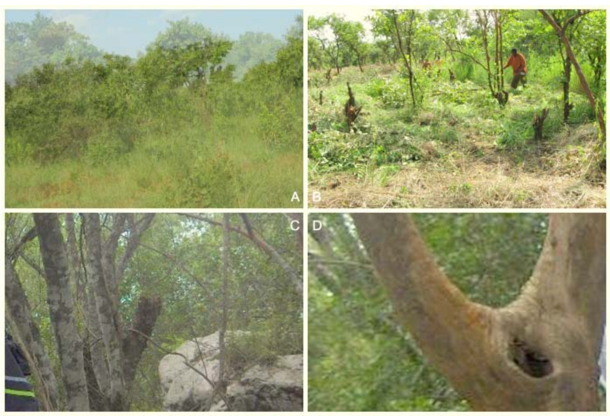

Fig. 1. Kasagala forest reserve – Clockwise from top: (A). Typical savanna vegetation of the reserve, (B). Anthropogenic activities are apparent here – research team inspecting a freshly cleared part of the nature reserve. A few large-stemmed tree individuals are only left at top of Kasagala hill such as these *Euclea latidens* Stapf (C) and *Nuxia floribunda* Benth (D).

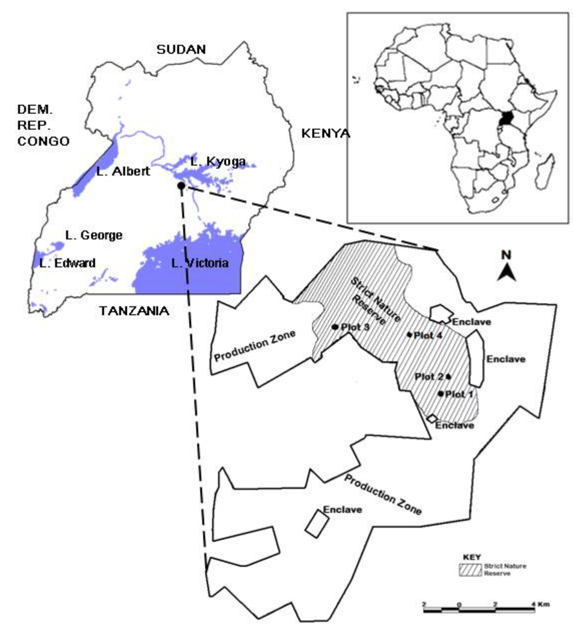

Fig. 2. Location of Kasagala woodland forest reserve in Uganda.

Methods

We established four permanent sample plots (PSPs) in the strict nature reserve of Kasagala woodland forest in central Uganda, using a sampling intensity of 0.08% (adapted from Alder and Synnot [22]). The woodland is located between 0^0 55′ and 1^0 33′ N and 32^0 00′ and 32^0 35′ E and lies at altitude of 1,100 m above sea level [23]. It was gazetted in 1932 for biodiversity conservation and watershed protection [20]. The forest has been described by Langdale-Brown et al. [24] as dominated by *Combretum – Terminalia – Loudetia* savanna. It is not particularly biodiverse, although it contains a regional endemic species, *Vernonia iodacalyx* O.Hoffm. and a particularly high diversity of butterflies (76 species) as compared to other Ugandan woodlands [23].

Establishment and design of permanent sample plots

We utilized the current zoning system in Kasagala woodland forest as a basis for setting up the PSPs. The forest is zoned into a production zone and strict nature reserve (Figure 2). We established the PSPs in the strict nature reserve due to its relative protection and the minimum likelihood of human disturbance. The PSPs were located in four vegetation strata that are representative of the vegetation of the strict nature reserve (Figure 2).

Plot demarcation and marking

We established a 1-ha (100 × 100 m) PSP in each of the strata using a magnetic northeast directional alignment. To avoid destruction by grazing animals, we constructed clearly marked concrete 1 × 1 m L–shaped cairns reinforced with metal studs at each of the four corner points of each plot. In addition, we constructed concrete cairns at all the 50m mid-point locations of every 100 m stretch of the plot boundaries. We geo-referenced all corner points of the plots with the aid of a Garmin 12 × Global Positioning System (GPS) for ease of re-locating them in future.

We divided each plot into four quadrats of 50 × 50 m and enumerated all trees and shrubs that measured ≥ 5 cm DBH. We identified all the trees and shrubs in each quadrat to species level with the help of a field taxonomist and relevant field identification guides like Eggeling [25], Beentje [26], Blundell [27] and Mabberley [28].

Data processing and analysis

We tested for similarities in tree species richness/abundance between the different vegetation strata by performing an analysis of similarities (ANOSIM) based on Bray-Curtis distances. We also performed a Similarity Percentages (SIMPER) analysis to determine the percent contribution of each species to the similarities in species abundance. A Kruskal-Wallis test was applied to show the differences in mean number of species in each vegetation type.

In measuring ecosystem structure, taxonomic diversity (Δ) and taxonomic distinctness (Δ^*) indices utilize relatedness (species, genus, family, order, etc.) among the measurement units in the population [17]. We utilized three levels of taxonomic information (species, genus, and family) to determine the taxonomic diversity (Δ) and taxonomic distinctness (Δ^*) for each of the vegetation strata by bootstrapping from 200 random replicates of the total tree counts at 95% confidence interval. All analyses were performed in the Paleontological Statistics (PAST) software version 1.89 [29].

Results

The species abundance ranged from 33 to 41 tree/shrub species per plot (mean = 29). *Ficus* was the most highly speciose family (9 species) while *Acacia* and *Albizia* each had 4 and 3 species, respectively. *Combretum*, *Euclea*, *Grewia*, *Maytenus*, *Oncoba*, *Rhus* and *Vitex* were represented by two species each, while the rest of the genera had one species each. *Combretum* was highly abundant in plot 3 but much less in the other vegetation strata (see Appendix 1).

Table 1. Descriptive statistics of the vegetation strata in Kasagala forest, Uganda.

Vegetation strata	*Elev. (m. asl.)*	*Stem count*	*No. of species*	*Taxonomic diversity*			*Taxonomic distinctness*		
				Calculated	Low	High	Calculated	Low	High
Dry *Mystroxylon - Hymenocardia* woodland	1145	1459	37	2.41	2.70	2.73	2.97	2.96	2.97
Dry *Euphorbia - Combretum* thicket woodland	1073	501	41	2.79	2.68	2.75	2.98	2.95	2.97
Seasonally flooded grass and herb savanna	1060	330	35	2.66	2.67	2.76	2.90	2.96	2.97
Dry sparsely wooded savanna	1070	455	33	2.51	2.68	2.75	2.97	2.95	2.97

Of the 69 species encountered, 13 occurred in all the vegetation strata, while 13 occurred in three strata (Appendix 1). SIMPER analysis showed that less than half (n = 31) of the species occurred in only one plot. Most species had low abundances (Fig. 3a-d). Ten species of highest abundance (14% of the total number of species) contained over 72% of all trees and shrubs encountered. For 14.5% of the species, only one individual tree was encountered, whereas 55% of the species had 10 or fewer individuals. There was no significant difference in species richness in the four vegetation strata (Kruskal Wallis: H = 2.614, H_c = 2.923, p = 0.453; ANOSIM: R = -0.334, p = 0.995). The species rank/abundance curves showed that the species distributions were unevenly distributed (Fig. 3a-d). Plots 1 and 4 had the most uneven species distribution of the four sample plots (Fig. 3a & d). *Mystroxylon aethiopicum* (Thunb.) Loes accounted for 39% while *Hymenocardia acida* Tul. and *Combretum collinum* Fresen each accounted for 10% of the abundance in plot 1. Similarly, *Rhus natalensis* Bernh. Ex Krauss, the most dominant species in plot 4, accounted for over 34% of the abundance in this vegetation stratum. Plots 2 and 3 had more than one dominant species.

The taxonomic diversity (Δ) and distinctness (Δ^*) of the four vegetation types was generally even, suggesting a homogeneous community. The values of taxonomic diversity ranged between 2.414 and 2.786 (95% bootstrapped CI values ranged between 2.680 and 2.758), while the taxonomic distinctness values ranged between 2.897 and 2.978 (95% bootstrapped CI values ranged between 2.953 and 2.974) (Table 1). Plot 2 had the highest taxonomic diversity and distinctness (Δ= 2.786, Δ*= 2. 978). The lowest taxonomic diversity (Δ=2.414) was observed in plot 1 while plot 3 had the lowest taxonomic distinctness (Δ*=2.897). Generally, the values of taxonomic diversity were lower, while those for taxonomic distinctness were higher than would have been expected to occur by random chance except in plots 2 and 3. The taxonomic diversity value for plot 2 was higher than the 95% confidence interval. The taxonomic distinctness value for plot 3 was lower than would have been expected by chance. Plot 3 was a seasonally flooded grass and herb savanna and seems to have been highly impacted by anthropogenic pressures. This plot had the least number of woody plants ≥ 5 cm DBH.

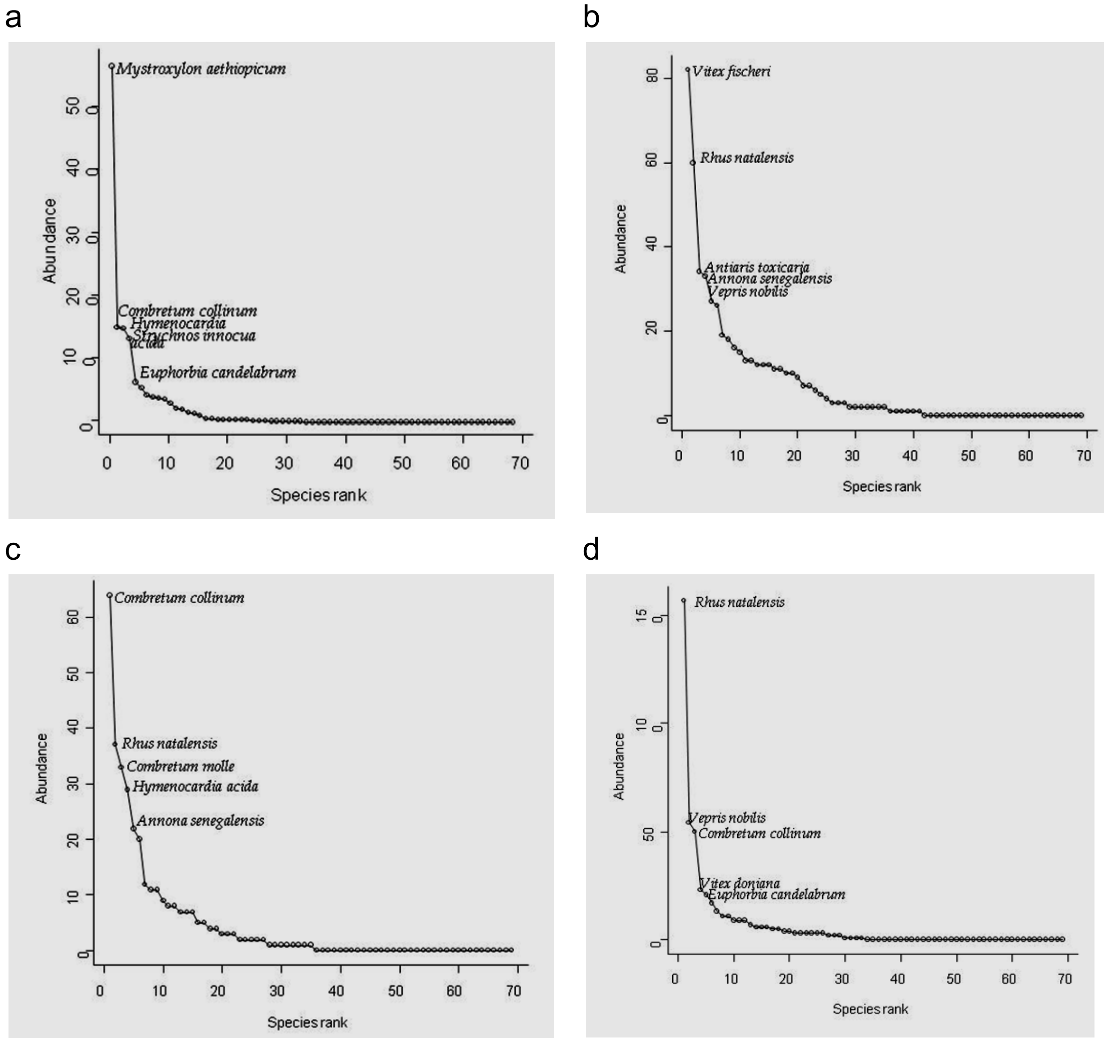

Fig. 3a-d. Rank abundance curves for five most abundant species in the four vegetation strata: (a) Plot 1: Dry *Mystroxylon – Hymenocardia* woodland (b) Plot 2: Dry *Euphorbia – Combretum* thicket woodland (c) Plot 3: Seasonally flooded grass and herb savanna, and (d) Plot 4: Dry sparsely wooded savanna.

Discussion

Species abundance

Although Kasagala woodland forest has been described as a dry *Combretum* woodland [24], we found that the most abundant tree species are *M. aethiopicum* and *R. natalensis*, suggesting a change in species dominance. In this study, the rank abundance curves (Fig. 3a-d) suggest an uneven species distribution in all the vegetation strata. The highly ranked species are more abundant than the low-ranking species. Changes in species dominance have important consequences on local-level and spatial processes including mechanism of species coexistence [30]. Species abundance measures also show species integrity and effect of habitat degradation on biodiversity [31]. Ranking species abundance is a useful method of representing dominant as well as under-represented species. According to Hildebrand and others [30], factors that increase or decrease the dominance in a community alter the distribution of traits in the community, which also determines the community resistance or resilience to disturbance.

The numerical dominance of *M. aethiopicum* in plot 1 and *R. natalensis* in plot 4 suggest that these species either possess high regeneration rates or face less anthropogenic selection compared to other species in the woodland forest. Kasagala woodland forest was previously described as a *Combretum*-dominated forest [24]. However, *Combretum* species in Uganda's woodlands are currently facing serious extraction pressure as the favored species for charcoal production and firewood [32]. While we cannot exclusively infer that this is the main factor shaping the species-dominance relationship presently in Kasagala forest reserve, changes in dominance found in the present study indicate that the dominant species of this woodland forest reserve have changed over time. The spatial distribution and community composition in the four vegetation strata suggest a combination of forces shaping this vegetation community (cf. Fig. 1c). As such, this woodland forest may not be described as *Combretum*-dominated woodland as other tree/shrub species like *M. aethiopicum* and *R. natalensis* have become more abundant [33].

Taxonomic diversity and distinctness

Taxonomic diversity and distinctness have been widely employed in marine ecology to show the integrity of communities and habitat conservation status [31, 34-38]. Taxonomic diversity and distinctness indices are appropriate for indicating the effect of anthropogenic disturbances and degradation of biotic communities [39, 40]. Although the effects of anthropogenic influences on species richness were not examined, heavy grazing and browsing and rampant charcoal burning in the forest were observed, especially in the low-lying areas of plot 3.

The taxonomic distinctness values for this woodland depict a homogenous woodland that has been degraded by human activities. Taxonomic diversity (Δ) and distinctness (Δ^*) values fall outside the 95% confidence interval, implying this woodland forest is homogeneous. However, the seasonally flooded grass and herb savanna faces disturbances and perturbations to its species stability as evidenced by its low taxonomic distinctness. As noted by Warwick [34], perturbed communities tend to have reduced taxonomic distinctness, being composed on average of more closely related species than unperturbed communities, which tend to have more taxonomically distant species thus resulting in greater taxonomic distinctness. We conclude that the low taxonomic distinctness value for plot 3 is a result of anthropogenic influences. Although anthropogenic activity was not part of this investigation, we observed high presence of cattle and goats grazing in the woodland forest, as well as charcoal production and firewood harvesting in this lowland vegetation type. This is a common phenomenon in

Uganda's woodland forests that supply fuel wood and building poles [41]. Continued and uncontrolled removal of tree species such as *Combretum* for firewood and charcoal will alter the composition and structure of the woodland forest and adversely affect its biodiversity and ecosystem functions.

Table 2. Ranking of 20 most abundant species in Kasagala woodland forest

Species	Rank	Abundance	Proportion
Mystroxylon aethiopicum	1	580	21.1
Combretum collinum	2	275	10.0
Rhus natalensis	3	256	9.3
Hymenocardia acida	4	190	6.9
Strychnos innocua	5	139	5.1
Vitex fischeri	6	132	4.8
Vepris nobilis	7	129	4.7
Euphorbia candelabrum	8	98	3.6
Annona senegalensis	9	95	3.5
Combretum molle	10	88	3.2
Lannea kerstingii	11	86	3.1
Antiaris toxicaria	12	80	2.9
Euclea latidens	13	46	1.7
Ziziphus abyssinica	14	42	1.5
Grewia holstii	15	40	1.5
Vangueria apiculata	16	36	1.3
Cussonia arborea	17	35	1.3
Vitex doniana	18	25	0.9
Albizia zygia	19	23	0.8
Piliostigma thonningii	20	23	0.8

Implications for conservation

Woodlands are important for the provision of goods and services that promote development and livelihood opportunities. Some of these goods include firewood, timber, poles, charcoal, and other minor produce. On the other hand, the services include watershed protection, soil erosion control, and shade. Although the value of these goods and services is vast, wise management and conservation decisions require the availability of empirical data on the need for such conservation. However, as noted by Namaalwa [42], these data are scarce for Ugandan woodlands. Due to the paucity of empirical data and the need to generate information that can be used for conservation and policy decisions, Kasagala forest was identified as a candidate woodland for this study. While several woodlands around Lake Kyoga were gazetted in the 1930s to provide catchment protection to the lake system, Kasagala forest is seriously threatened by the exploitation of its woodland resources for charcoal, firewood, and poles (Figure 3b). The findings of this study are therefore important in suggesting policy and conservation recommendations for this and similar woodland forests in Uganda that are in dire need of conservation.

This study has revealed that this forest is not especially species diverse. The pattern of tree abundance showed that the highest tree stem density in this forest can only be found in the high-altitude parts of the forest (plot 1) (Table 1, Appendix 1). Indeed, *M. aethiopicum*, the most abundant tree species in the forest, is dominant in the high-altitude part of the forest and only occurs in fewer numbers in the adjoining lowland areas (Fig. 3a, Appendix 1). This implies that while management and conservation efforts are required for the whole forest ecosystem, the main areas of concern are the lowland areas where tree extraction may be more apparent due to ease of access by grazers and encroachers. Indeed, as shown in Fig. 1b, creation of a strict nature reserve has not afforded the forest the protection that would be expected. Given such a scenario then, management and conservation of the different vegetation strata of the forest require a community conservation approach that includes serious awareness and sensitization to the people around the forest. This may be the most tenable approach; these woodlands are located in the most poverty-stricken parts of the country, where over 50% of the population can be described as poor and living on less than one dollar per day [43]. Although this system of community participation in the management of forest resources is presently practiced in Uganda's tropical high forests, it has not been used for woodland resources as is the case in Tanzania's Miombo woodlands [44].

While Kasagala forest has historically been known for its stocks of *Combretum* trees, leading to its description as a *Combretum*-dominated woodland by Langdale-Brown and others [24], evidence from this study shows that *Combretum* species make up only 13% of the total stems counted (Table 2). *Combretum* is most dominant only in plot 3 – the seasonally flooded grass and herb savanna. As noted by Kalumiana and Kisakye [32], *Combretum* species are heavily harvested in Uganda's woodlands on account of the high-quality charcoal they produce. Unless this harvesting is checked, this can develop into a typical "tragedy of the commons" as people strive to obtain means of livelihood through extraction of the most commercially valuable species. Such selective extraction ultimately impacts on ecosystem structure and functioning including species interactions and resilience. Although enrichment planting is a common practice for replenishing depleted stocks of common tree species in natural high forests, this is not yet the case for savanna woodland species for which silvicultural techniques are not yet refined or even established in Uganda. This is, however, a possible solution for the restoration of degraded woodlands such as Kasagala forest.

Acknowledgements

We thank the Government of Uganda for funding this work through the National Agricultural Research Organization (NARO), and the National Forest Authority (NFA) for granting access to Kasagala woodland forest. We gratefully thank Cathy Namome and Richard Akope who assisted with data collection. Finally, we would like to thank two anonymous reviewers whose comments were extremely useful in refining an earlier draft of this paper.

References

[1] Dekker, M., Turnhout, E., Bauwens, B. M. S. D. L., and Mohren, G. M. J. 2007. Interpretation and implementation of ecosystem management in international and national forest policy. *Forest Policy and Economics* 9(5): 546-557.

[2] Pearce, D. W. 2001. The economic value of forest ecosystems. *Ecosystem Health* 7(4): 284-296.

[3] Malhi, Y., Phillips, O. L., Lloyd, J., Baker, T., Wright, J., Almeida, S., Arroyo, L., Frederiksen, T., Grace, J., Higuchi, N., Killeen, T., Laurance, W. F., Leaño, C., Lewis, S., Meir, P., Monteagudo, A., Neill, D., Núñez-Vargas, P., Panfil, S. N., Patiño, S., Pitman, N., Quesada, C. A., Rudas-Li, A., Salomão, R., Saleska, S., Silva, N., Silveira, M., Sombroek, W. G., Valencia, R., Vásquez-Martínez, R., Vieira, I. C. G., Vinceti, B., Canadell, J., and White, P. S. 2009. An international network to monitor the structure, composition and dynamics of Amazonian forests (RAINFOR). *Journal of Vegetation Science* 13(3): 439-450.

[4] Phillips, O. L., Malhi, Y., Vinceti, B., Baker, T., Lewis, S. L., Higuchi, N., Laurance, W. F., Vargas, P. N. E., Martinez, R. V., Laurance, S., Ferreira, L. V., Stern, M., Brown, S., and Grace, J. 2002. Changes in growth of tropical forests: evaluating potential biases. *Ecological Applications* 12(2): 576-587.

[5] Sagar, R., and Singh, J. S. 2004. Local plant species depletion in a tropical dry deciduous forest of northern India. *Anglais* 31(1): 55-62.

[6] Steininger, M. K., Tucker, C. J., Ersts, P., Killeen, T. J., Villegas, Z., and Hecht, S. B. 2001. Clearance and fragmentation of tropical deciduous forest in the Tierras Bajas, Santa Cruz, Bolivia. *Conservation Biology* 15: 856-866.

[7] Buntaine, M., Mullen, R., and Lassoie, J. 2007. Human use and conservation planning in Alpine areas of Northwestern Yunnan, China. *Environment, Development and Sustainability* 9: 305-324.

[8] Hunt, C. 2002. Local and global benefits of subsidizing tropical forest conservation. *Environment and Development Economics* 7(2): 325-340.

[9] Naidoo, R., and Adamowicz, W. L. 2005. Economic benefits of biodiversity exceed costs of conservation at an African rainforest reserve. *Proceedings of the National Academy of Sciences of the United States of America* 102(46):16712-16716.

[10] Godoy, R., Wilkie, D., Overman, H., Cubas, A., Cubas, G., Demmer, J., McSweeney, K., and Brokaw, N. 2000. Valuation of consumption and sale of forest goods from a Central American rain forest. *Nature* 406(6791): 62-63.

[11] Naidoo, R., and Ricketts, T. H. 2006. Mapping the economic costs and benefits of conservation. *PLoS Biol* 4(11): e360.

[12] Beetson, T., Nester, M., and Vanclay, J. 1992. Enhancing a permanent sample plot system in natural forests. *The Statistician* 41(5):525-538.

[13] Okoti, M., Ng’ethe, J. C., Ekaya, W. N., and Mbuvi, D. M. 2004. Land use, ecology, and socio-economic changes in a pastoral production system. *Journal of Human Ecology* 16(2): 83-89.

[14] Mérigot, B., Bertrand, J. A., Gaertner, J-C., Durbec, J-P., Mazouni, N., and Manté, C. 2007. The multi-component structuration of the species diversity of ground fish assemblages of the east coast of Corsica (Mediterranean Sea): Variation according to the bathymetric strata. *Fisheries Research* 88(1-3): 120-132.

[15] Tolimieri, N., and Anderson, M. J. 2010. Taxonomic distinctness of demersal fishes of the California current: Moving beyond simple measures of diversity for marine ecosystem-based management. *PLoS ONE* 5(5): e10653.

[16] Ricotta, C. 2005. Through the jungle of biological diversity. *Acta Biotheoretica* 53: 29-38.

[17] Clarke, K. R., and Warwick, R. M. 1998. A taxonomic distinctness index and its statistical properties. *Journal of Applied Ecology* 35: 523-531.

[18] da Silva, I. A., and Batalha, M. A. 2006. Taxonomic distinctness and diversity of a hyper seasonal savanna in central Brazil. *Diversity and Distributions* 12: 725-730.
[19] Domínguez, L. F., Price, J., Otto, R., and Fernández-Palacios, J. M. 2010. Using taxonomic and phylogenetic evenness to compare diversification in two Island Floras. *Perspectives in Plant Ecology, Evolution and Systematics* 12(2): 93-106.
[20] NFA. 2005. *Uganda's Forests, Functions and Classification*. National Forestry Authority, Kampala, Uganda.
[21] Bush, G., Nampindo, S., Aguti, C., and Plumptre, A. 2004. *The Value of Uganda's Forests: A Livelihoods and Ecosystems Approach*. Wildlife Conservation Society, Kampala, Uganda.
[22] Alder, D., and Synott, T. 1992. *Permanent Sample Plot Techniques for Mixed Tropical Forest*. Oxford Forestry Institute, Oxford, United Kingdom.
[23] Davenport, T., Howard, P., and Baltzer, M. 1996. *Luwero District Forest Reserves*. Biodiversity Report, Forest Department, Kampala, Uganda.
[24] Langdale–Brown, I., Osmaston, H. A., and Wislon, J. G. 1964. *The Vegetation of Uganda and its bearing on Land-use*. Government Printer, Entebbe, Uganda.
[25] Eggeling, W. J. 1951. *The Indigenous Trees of the Uganda Protectorate*. Revised and enlarged by I. R. Dale. Government Printer, Entebbe, Uganda.
[26] Beentje, H., Adamson, J., and Bhanderi, D. 1994. *Kenya Trees, Shrubs, and Lianas*. National Museums of Kenya, Nairobi, Kenya.
[27] Blundell, M. 1987. *Collins Guide to the Wild Flowers of East Africa*. Collins, London, United Kingdom.
[28] Mabberley, D. J. 1997. *The Plant Book: A Portable Dictionary of the Vascular Plants*. 2nd Edition, Cambridge University Press, Cambridge, United Kingdom.
[29] Hammer, Ø., Harper, D. A. T., and Ryan, P. D. 2001. PAST: Palaeontological Statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1): 9.
[30] Hillebrand, H., Bennett, D. M., and Cadotte, M. W. 2008. Consequences of dominance: a review of evenness effects on local and regional ecosystem processes. *Ecology* 89(6): 1510-1520.
[31] Leonard, D. R. P., Clarke, R. K., Somerfield, P. J., and Warwick, R. M. 2006. The application of an indicator based on taxonomic distinctness for UK marine biodiversity assessments. *Journal of Environmental Management* 78(1): 52-62.
[32] Kalumiana, O. S., and Kisakye, R. 2001. *Study on the establishment of a sustainable charcoal production and licensing system in Masindi and Nakasongola districts*. ACDI/VOCA EPED Project Report, Masindi, Uganda.
[33] Gwali, S., Okullo, P., Hafashimana, D., and Byabashaija, D. M. 2010. Diversity and composition of trees and shrubs in Kasagala forest: a semiarid savannah woodland in central Uganda. *African Journal of Ecology* 48: 111-118.
[34] Warwick, R. M., and Clarke, K. R. 1995. New 'biodiversity' measures reveal a decrease in taxonomic distinctness with increasing stress. *Marine Ecology Progress Series* 129: 301-305.
[35] Hall, S. J., and Greenstreet, S. P. 1998. Taxonomic distinctness and diversity measures: responses in marine fish communities. *Marine Ecology Progress Series* 166: 227-229.
[36] Rogers, S. I., Clarke, K. R., and Reynolds, J. D. 1999. The taxonomic distinctness of coastal bottom-dwelling fish communities of the North-east Atlantic. *Journal of Animal Ecology* 68: 769-782.
[37] Brown, B. E., Clarke, K. R., and Warwick, R. M. 2002. Serial patterns of biodiversity change in corals across shallow reef flats in Ko Phuket, Thailand, due to the effects of local (sedimentation) and regional (climatic) perturbations. *Marine Biology* 141(1): 21-29.

[38] Warwick, R. M., and Light, J. 2002. Death assemblages of molluscs on St Martins Flats, Isles of Scilly: a surrogate for regional biodiversity? *Biodiversity and Conservation* 11: 99-112.
[39] Heino, J., Mykr, H., Kotanen, J., and Muotka, T. 2007. Ecological filters and variability in stream macroinvertebrate communities: Do taxonomic and functional structure follow the same path? *Ecography* 30: 217-230.
[40] Warwick, R. M., and Clarke, K. R. 1998. Taxonomic distinctness and environmental assessment. *Journal of Applied Ecology* 35: 532-543.
[41] Baranga, D. 2007. Observations on resource use in Mabira Forest Reserve, Uganda. *African Journal of Ecology* 45: 2-6.
[42] Namaalwa, J. 2006. The growth, use and management of woodland resources in Uganda. PhD Thesis, Norwegian University of Life Sciences (UMB), Norway.
[43] Rogers, D., Emwanu, T., and Robinson, T. 2006. Poverty Mapping in Uganda: An Analysis Using Remotely Sensed and other Environmental Data. Pro-Poor Livestock Policy Initiative (PPLPI) Working Paper No. 36. FAO, Rome, Italy.
[44] Topp-Jørgensen, E., Poulsen, M. K., Lund, J. F., and Massao, J. F. 2005. Community-based Monitoring of Natural Resource Use and Forest Quality in Montane Forests and Miombo Woodlands of Tanzania. *Biodiversity and Conservation* 14: 2653-2677

Appendix 1. Tree/shrub species inventoried from Kasagala woodland forest

Species	Family	Abundance			
		Number of stems			
		Plot1	Plot2	Plot3	Plot4
Acacia hockii De Wild.	Fabaceae	4	2	8	3
Acacia polyacantha Willd.	Fabaceae	0	0	0	1
Acacia senegal (L.) Willd.	Fabaceae	0	0	1	0
Acacia sieberiana DC.	Fabaceae	0	0	2	4
Albizia coriaria Oliver	Fabaceae	1	15	2	3
Albizia gummifera (J. F. Gmel.) C. A. Sm.	Fabaceae	2	0	0	2
Albizia zygia (DC.) J.F.Macbr.	Fabaceae	6	2	12	3
Allophylus africanus P. Beauv.	Sapindaceae	0	0	7	11
Annona senegalensis Pers.	Annonaceae	31	33	22	9
Antiaris toxicaria Lesch.	Moraceae	41	34	5	0
Bridelia scleroneura Müll. Arg.	*Euphorbia*ceae	3	4	1	5
Carissa edulis (Forssk.) Vahl	Apocynaceae	0	3	0	0
Combretum collinum Fresen.	Combretaceae	150	11	64	50
Combretum molle R. Br. ex G. Don	Combretaceae	36	19	33	0
Cussonia arborea Hochst. ex A. Rich.	Araliaceae	5	16	5	9
Dombeya burgessiae Gerrard ex Harv.	Sterculiaceae	0	0	2	0
Ekebergia senegalensis A. Juss.	Meliaceae	1	0	0	0
Erythrina abyssinica Lam. ex DC.	Fabaceae	0	2	0	0
Euclea latidens Stapf	Ebenaceae	21	18	7	0
Euclea racemosa L.	Ebenaceae	0	1	0	0
Euphorbia candelabrum Tremaux ex Kotschy	*Euphorbia*ceae	64	13	0	21
Ficus glumosa Delile	Moraceae	14	0	1	0
Ficus ingens (Miq.) Miq.	Moraceae	0	0	0	1
Ficus lutea Vahl	Moraceae	0	0	1	0
Ficus natalensis Hochst.	Moraceae	0	0	1	0
Ficus ottoniifolia (Miq.) Miq.	Moraceae	0	0	0	6
Ficus ovata Vahl	Moraceae	0	0	2	0

Ficus sur Forssk.	Moraceae	0	3	0	0
Ficus sycomorus L.	Moraceae	0	2	0	2
Ficus thonningii Blume	Moraceae	3	7	0	0
Flueggea virosa (Roxb. ex Willd.) Voigt	*Euphorbia*ceae	0	0	0	3
Gardenia ternifolia Schumach. & Thonn.	Rubiaceae	0	0	7	3
Grewia holstii Burret	Tiliaceae	15	10	9	6
Grewia mollis Juss.	Tiliaceae	0	3	1	13
Harrisonia abyssinica Oliv.	Simaroubaceae	0	2	3	0
Hymenocardia acida Tul.	*Euphorbia*ceae	151	10	29	0
Lannea kerstingii Engl. & K. Krause	Anacardiaceae	55	12	8	11
Margaritaria discoidea (Baill.) G.L. Webster	*Euphorbia*ceae	0	2	0	0
Maytenus senegalensis (Lam.) Exell	Celastraceae	2	0	0	0
Maytenus undata (Thunb.) Blakelock	Celastraceae	0	1	0	17
Milicia excelsa (Welw.) C.C. Berg	Moraceae	0	0	1	0
Mystroxylon aethiopicum (Thunb.) Loes.	Celastraceae	567	13	0	0
Nuxia floribunda Benth.	Buddlejaceae	12	5	0	4
Ochna afzelii R.Br. ex Oliv.	Ochnaceae	4	0	0	0
Oncoba routledgei Sprague	Flacourtiaceae	0	6	0	0
Oncoba spinosa Forssk.	Flacourtiaceae	4	0	0	0
Ozoroa insignis Delile	Anacardiaceae	2	0	0	0
Pappea capensis Eckl. & Zeyh.	Sapindaceae	1	1	20	0
Piliostigma thonningii (Schumach. & Thonn.) Milne-Redh.	Fabaceae	0	12	2	9
Protea madiensis Oliv.	Proteaceae	4	0	0	0
Rhus natalensis Bernh.	Anacardiaceae	2	60	37	157
Rhus vulgaris Meikle	Anacardiaceae	2	0	0	0
Scutia maritima Perkins	Rhamnaceae	0	0	0	3
Securidaca longipedunculata Fresen.	Polygalaceae	6	0	0	0
Senna spectabilis (DC.) H. S. Irwin & Barneby	Fabaceae	0	0	4	0
Steganotaenia araliacea Hochst.	Apiaceae	0	9	3	6

Stereospermum kunthianum Cham.	Bignoniaceae	3	11	1	7
Strychnos innocua Delile	Loganiaceae	134	1	3	1
Tamarindus indica L.	Fabaceae	0	7	0	0
Trichilia emetica Vahl	Meliaceae	0	2	0	0
Trichilia martineaui Aubrév. & Pellegr.	Meliaceae	1	1	0	0
Trichilia prieuriana A. Juss.	Meliaceae	5	0	0	0
Vangueria apiculata K.Schum.	Rubiaceae	22	12	0	2
Vepris nobilis (Delile) W. Mziray	Rutaceae	44	27	4	54
Vitex doniana Sweet	Verbenaceae	2	0	0	23
Vitex fischeri Gürke	Verbenaceae	39	82	11	0
Ximenia americana L.	Olacaceae	0	0	0	1
Zanthoxylum chalybeum Engl.	Rutaceae	0	1	0	0
Ziziphus abyssinica Hochst. ex A. Rich.	Rhamnaceae	0	26	11	5
Total		**1459**	**501**	**330**	**455**