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RESEARCH ARTICLE

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Spatial Distribution in Tree Species Composition, Abundance and Diversity in Embobut River Basin

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Abstract

Embobut Forest Reserve in Elgeyo Marakwet County is one of the five major water towers in Kenya where there is increasing encroachment by humans for settlement and agriculture. Therefore, the influence of settlement activities and biodiversity changes need to be assessed. This study carried out an inventory to monitor the distribution of trees in terms of species composition, abundance and diversity in Embobut River Basin along an altitudinal gradient characterized by valley floor, escarpment, upper forested area and the moorland/montane region. Transect and quadrant methods were used as sampling techniques. A checklist was used to characterize tree species composition with a corresponding presence/absence data at each of the site blocks. Species distribution in terms of presence/absence and abundance was determined using cluster analysis. The results showed that there were 41 tree species belonging to 24 families. The valley floor had the highest frequency of tree (16) followed by escarpment (15), then upland forests (9) and least in montane region (8). No single species occurred at all site probably due to high degree of specialization in their endemic ecological zone. Few species such as Vachelia tortilis, Senegalia meliffera, Boscia coriacea, Bersama abysinica and Balanites pedicellaris showed wide distribution in terms of composition and abundance beyond their native habitats. The montane region had the highest species diversity followed by escarpment and the least abundant region was the valley floor. The present study demonstrates low distribution in tree composition, abundance and diversity which may have resulted from human encroachment of the Embobut River Basin.

Keywords: Plants Species, Plant Composition, Plant Distribution, Plant Diversity, Embobut River Basin

INTRODUCTION

Forest occupies about 6% of the earth surface, and estimated to contain 50-65% of the 5-10 million species of flora and fauna (Jones *et al.*, 2018). In undisturbed forests, tree species composition, abundance and diversity reflects the influence of natural physical and chemical environment (Quaresma *et al.*, 2018). The wide variation in tree species distribution in terms of species composition, abundance and diversity across ecosystems is therefore is a reflection of the health of these ecosystems (McGlinn *et al.*, 2019; Norberg *et al.*, 2019; Soriano-Redondo *et al.*, 2019). Among the various ecosystems in the biosphere, mountainous regions rank among the richest in not only tree but general floral biodiversity (Bogale *et al.*, 2017; Malanson *et al.*, 2019; Niu *et al.*, 2019). Tropical or Afromontane ecosystems are undeniably among the most plant species-rich ecosystems on earth (Asfaw, 2018; Awoke & Mewded, 2019; Gadow *et al.*, 2016; Reshad & Beyene, 2019), yet some tropical forest zones remain less studied. Most of the studies of Afro-montane ecosystem have concentrated in mountain forests of Ethiopia where there is much knowledge on the spatial distribution of the species in terms of composition, abundance and diversity (Awoke & Mewded, 2019; Aynekulu *et al.*, 2016; Reshad & Beyene, 2019; Seta *et al.*, 2019; Siyum *et al.*, 2019), However, other Afromontane regions have remained scantily studied in terms of tree species distribution. This is particularly of concern especially in unique Afromontane ecosystem in Kenya (Los *et al.*, 2019).

In Kenya, there is massive settlement of people in several forest region which may affect the overall biodiversity in these forests (Muhati *et al.*, 2018; Njue *et al.*, 2016). Through human influences and other processes, many of the dense forested areas in Kenya have been lost resulting in loss of biodiversity, in ecosystems that previously had rich biotic assemblages threatening the very existence of most forest ecosystems (Bett *et al.*, 2017; Chirchir *et al.*, 2018; Schmitt *et al.*, 2019) causing increasing concern about the biological integrity of forests in Kenya (Mandela *et al.*, 2018). Any further exploitation of forest vegetation is only bound to further strain these resources leading to even more adverse consequences for the ecosystem (Mutoko *et al.*, 2015).

There is growing international agreement on the need for effective priority setting, planning, conservation action, and monitoring to address current threats to the world's forests and the biodiversity (Busck-Lumholt & Treue, 2018; Ndang'ang'a *et al.*, 2016). But conservation action must be supported by accurate data on various aspects of forest biodiversity. As part of this effort, the Kenya Forest Service (KFS), through the implementation of the new Kenya Forest Act (2005) is getting into management partnerships with communities living adjacent to natural forests. Part of the requirements of these partnerships is that forest management plans which must be prepared and implemented. Absence of site-specific studies on plant species distribution make generalization of the drivers of floral changes based on data from other studied areas unrealistic for local biodiversity studies. Despite their important contribution to those mainstream studies and also to conservation initiatives, there are not many wide-scale quantitative assessments of the present-day tree species distribution of subtropical forests. Therefore, floristic studies need to be carried out to generate baseline information crucial for drawing these management plans. However, despite the presence of incomplete species checklists in a number of studies on the forest ecosystems in Kenya, there are no detailed and reliable studies documented on the floristic richness in forests undergoing human encroachment such as Embobut Forest. On the basis of the foregoing argument the current study was undertaken to determine the species composition, abundance and diversity of Embobut Forest Basin.

MATERIALS AND METHODS

Study Area

This study was conducted along the Embobut River Basin in the Elgeyo Marakwet County at latitude 1°10’ to 1°14’N and longitude 35°27’ to 35°42’E (Figure 1). Embobut is one of the administrative wards for the Marakwet East Constituency in Elgeyo Marakwet County, Kenya forming a water tower. Water tower is a concept used in Kenya to refer to elevated topography, usually forested, that acts as a water catchment from which several rivers emanate. The forest covers an area of 21,655 ha. The upper catchment is a hilly plateau with altitude ranging between 2200−3400 m above sea level (asl) while the lower part of the study area has altitude ranging between 1000-2200 m above sea level. The mean annual rainfall at the upper part is about 1100 mm although some areas receive up to 1500 mm with two peaks in April to May and August to October and a drier spell from November to February. Meanwhile at the lowlands, rainfall can be as low as 500 mm. The average temperature is range from 14° to 30°C where the uplands have much lower temperature February is the hottest month, and June is the coolest. The study area is covered by closed canopy of forest, bamboo formations, scrub, rock, grassland, moorland or heath with cultivation and plantations.

The highland areas are characterized by moderately weathered dark-reddish brown soils with a clay-loam texture, which are all associates of the Rift Valley volcanic soils. Cheranganyi Hills are made of metamorphic rocks with conspicuous quartzite ridges and occasional veins of marble. Soils are thin, drain freely and have a friable texture with layers of cellular iron stone. Brown loam soils occur in high altitude areas and they are derived from both volcanic and basement complex rocks. Streams to the west of the watershed feed the Nzoia river system which flows into Lake Victoria. Streams to the east flow to Kerio River system and Embobut River is amongst them.

The population of communities living around Embobut River Basin is 26,772 homesteads based on the KNBS (2010). The main human activities within the study areas include livestock grazing, pastoralism, crop and dairy farming. The main farming activities within the drainage areas include cultivation of maize (*Zea mays* L.), Irish potatoes (*Solanum tuberosum*), beans (*Phaseolus vulgaris* L.) and a variety of other non-cereal crops on a smaller scale, including cabbage (*Brassica oleracea var capitata* L. (Alef.) and kales (*Brassica oleracea var acephala* L. (DC.). Most of Embobut River Basin has been converted to farmland in the last 20 years (Chebet *et al.*, 2017).

Selection of Study Sites and Sampling

Embobut River basin was stratified into the Valley floor, Escarpment, Highland forests and Moorland as primary units through a ground pre-survey, guided by existing maps, existing literature and information from indigenous local people on site (Figure 1).

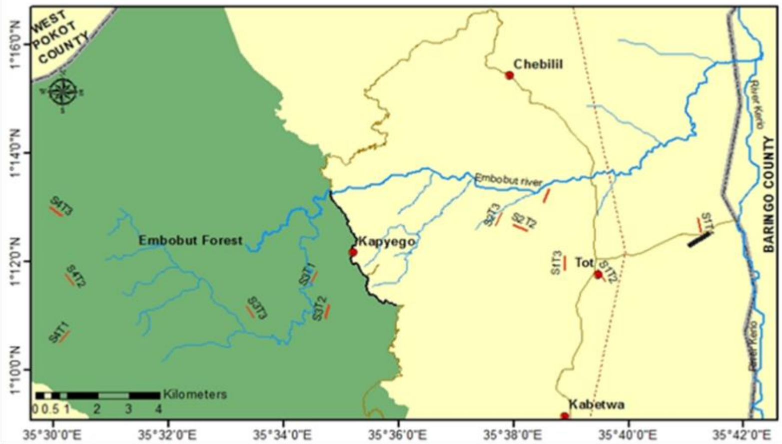

Figure 1. Map of the Study Area Showing the Location of the Sampling Points.

Vegetation Sampling Procedure

Three transects measuring 500 m long each were established in each of the sampling sites where three plots of 20 m × 20 m sizes evenly spaced at 230 m interval were established along the transect for quantitative sampling of trees. In each of the subplots, all woody plant species of diameter at breast height (DBH) ≥ 2.5 cm were measured and recorded. In case of coppicing trees, each stem was assessed separately (as applied by Howard 1991). The basic information gathered on vegetation characteristics included DBH (Diameter at Breast Height) for each tree with greater than 2.5 cm. Each plant was identified to species level. However, for those species that proved difficult to identify in the field, samples were collected, pressed and later taken to the University of Eldoret and East African herbaria where they were identified by matching with the herbarium specimens.

Data Analyses

All data collected were entered, organized and managed using Microsoft excel spreadsheet for Windows 98. All statistical analyses were performed using STATISTICA 6.0 (StaSoft, 2001) and Statistical Package for Social Sciences (SPSS version 23.0) Computer Package. Normality and homoscedasticity of data distribution was checked by means of the skewness and kurtosis (Pek *et al.*, 2018). In cases where data was found not to follow normal distribution (heteroscedastic), Log ($x + 1$) data transformation was used to normalize all the biological data (Ribeiro-Oliveira *et al.*, 2018). The mean abundance of plants species were calculated for each site. The spatial and temporal differences in species abundance between sites were obtained by determining the means and variance. Variation in plants abundance was analyzed using non-parametric Kruskal Wallis statistic (Kruskall & Wallis, 1952).

The total count of each tree species in the various forest sites was used to calculate the Shannon-Weiner index using the standard equation from Pielou (1975):

$$H' = \sum_{i=1}^{n} P_i (LnP_i)$$

Where: H’ = Shannon’s Weiner diversity index

P_i = the abundance of the i^{th} species expressed as a proportion of total cover.

To establish tree species distribution and community structure, the percentages of species contribution were subjected to exploratory cluster analysis. The dichotomous classification technique expressed the occurrence of organisms in an ordered table, constructed from site–taxa matrix. The outputs are viewed as dendrograms of tree species exhibiting similar species composition. For ease of comparison, the scale was reduced to percentage by dlink/dmax*100.

RESULTS

Information on the presence and absence of species at the four sites in Embobut Basin is shown in Table 1. The results showed that there were 41 tree species belonging to 24 families. The valley floor had the highest frequency of tree (16) followed by escarpment (15), then uplands (9) and least in montane (8). No single species occurred at all site. The valley floor was dominated by species in Capparaceae (*Boscia angustifolius*, *Boscia coriacea*, *Boscia mossambiscensis*) and Fabaceae (*Senegalia mellifera*, *Senegalia senegal*, *Vachellia nubica*, *Vachellia reficiens* and *Vachellia tortilis*) while in the escarpment the dominant species belonged to family Fabaceae (*Acacia hockii*, *Lonchocarpus eriocalyx*, *Senegalia mellifera*), while Anacardiaceae (*Lannea schimperi*, *Ozoroa insignis*), Combretaceae (*Combretum apiculatum*, *Combretum molle*), Ebenaceae (*Diospyros abyssinica*, *Euclea divinorum*) had two species each. There were no dominance of any family in the upland forest and montane region but occurrence of single specialized species within the region.

Table 1: Presence and Absence of Species at the Four Sites in Embobut Basin

Family	Species	Location			
		Valley floor	Escarpment	Upland forest	Montane region
Anacardiaceae	*Lannea schimperi*	-	x	-	-
	Ozoroa insignis	-	x	-	-
	Rhus natalensis	x	-	-	-
Araliaceae	*Schefflera volkensii*	-	-	-	x
Burseraceae	*Commiphora africana*	x	-	-	-
Capparaceae	*Boscia angustifolius*	x	-	-	-
	Boscia coriacea	x	-	-	-
	Boscia mossambiscensis	x	-	-	-
Cerastraceae	*Elaeodendron buchananii*	-	-	-	x
Combretaceae	*Combretum apiculatum*	-	x	-	-
	Combretum molle	-	x	-	-
	Terminalia brownii	x	-	-	-
Cornaceae	*Afrocrania volkensii*	-	-	x	-
Cupressaceae	*Juniperus procera*	-	-	-	x
Ebenaceae	*Diospyros abyssinica*	x	x	-	-
	Euclea divinorum	-	x	-	-
Ericaceae	*Erica arborea*	-		-	x
Euphorbiaceae	*Euphorbia candelabrum*	-	x	-	-
	Euphorbia canderubrum	-	x	-	-
	Neoboutonia macrocalyx	-	-	x	-
Fabaceae	*Acacia hockii*	-	x	-	-
	Lonchocarpus eriocalyx	-	x	-	-
	Senegalia mellifera	x	x	-	-
	Senegalia senegal	x	-	-	-
	Vachellia nubica	x	-	-	-
	Vachellia reficiens	x	-	-	-
	Vachellia tortilis	x	x	-	-
Hypericaceae	*Hypericum revolutum*	-	-	-	x
Malvaceae	*Grewia bicolor*	x	x	-	-
Melianthaceae	*Bersama abyssinica*	-	-	x	-
Pittisporaceae	*Pittosporum viridiflorum*	-	-	x	-
Primulaceae	*Maesa lanceolata*	-	-	x	-
	Rapanea melanophloeos	-	-	-	x
Rosaceae	*Hagenia abyssinica*	-	-	x	x
	Prunus africana	-	-	-	x
Rutaceae	*Teclea nobilis*	-	x	-	-
Salvadoraceae	*Salvadora persica*	x	-	-	-
Sapindaceae	*Allophyllus abyssinica*	-	-	x	-
Sterculiaceae	*Dombeya torrida*	-	-	x	-
Stilbaceae	*Nuxia congesta*	-	-	x	-
Zygophyllaceae	*Balanites aegyptiaca*	x	-	-	-
	Balanites pedicellaris	x	x	-	-

+ shows presence and – absence

In terms of distribution, *Vachelia tortilis*, *Senegalia mellifera*, *Boscia coriacea*, *Bersama abysinica* and *Balanites pedicellaris* showed wide distribution in terms of composition (Figure 2). Rank-abundance diagrams show the presence of many rare species with limited distribution.

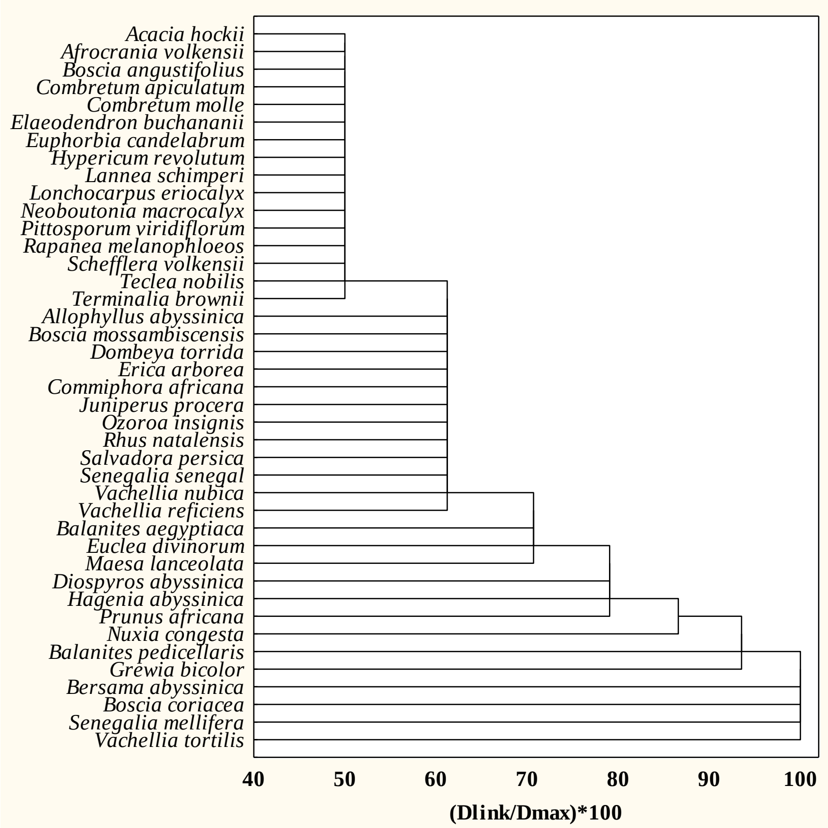

Figure 2: Distribution in Tree Species Composition at the Four Sites in Embobut Basin.

Information on the plant distribution in terms of abundance is shown in Table 2. Individually the high species abundance in the valley was contributed by *Boscia coriacea*, *Vachellia tortilis*, *Balanites pedicellaris*, *Diospyros abyssinica*, *Salvadora persica* and *Boscia mossambiscensis*. In escarpment the dominant plants species in terms of abundance were *Vachellia tortilis* and *Diospyros abyssinica* while in Upland forest the dominant forms was *Bersama abyssinica*, *Maesa lanceolata* and *Nuxia congesta* in montane forest the dominant species was *Rapanea melanophloeos*.

Table 2: Tree Abundance at Four Sampling Locations within the Embobut Basin

Species	Valley floor	Escarpment	Upland forest	Montane region
Acacia hockii		4		
Allophyllus abyssinica			4	
Afrocrania volkensii			1	
Balanites aegyptiaca	9			
Balanites pedicellaris	28	1		
Bersama abyssinica			23	1
Boscia angustifolius	1			5
Boscia coriacea	46			
Boscia mossambiscensis	13			
Combretum apiculatum		1		
Combretum molle		6		
Commiphora Africana	3			
Diospyros abyssinica	15	15		
Dombeya torrida			9	
Elaeodendron buchananii				3
Erica arborea				1
Euclea divinorum		10		
Euphorbia candelabrum		3		
Grewia bicolor	7	8		
Hagenia abyssinica			3	2
Hypericum revolutum				10
Juniperus procera				2
Lannea schimperi		1		
Lonchocarpus eriocalyx		1		
Maesa lanceolata			20	
Neoboutonia macrocalyx			1	
Nuxia congesta			14	
Ozoroa insignis		3		
Pittosporum viridiflorum			1	
Prunus Africana				1
Rapanea melanophloeos				24
Rhus natalensis	2			
Salvadora persica	14			
Schefflera volkensii				1
Senegalia mellifera	11	5		
Senegalia Senegal	8			
Teclea nobilis		5		
Terminalia brownii	2			
Vachellia nubica	8			
Vachellia reficiens	7			
Vachellia tortilis	32	30		
Total	**206**	**93**	**76**	**50**

In terms of distribution of the species abundance, *Vachelia tortilis*, *Boscia coriacea* and *Balanites pedicellaris*, showed wide distribution in terms of composition (Figure 3). Rank-abundance diagrams show the presence of many rare species in all the communities, but a higher proportion in the lowlands.

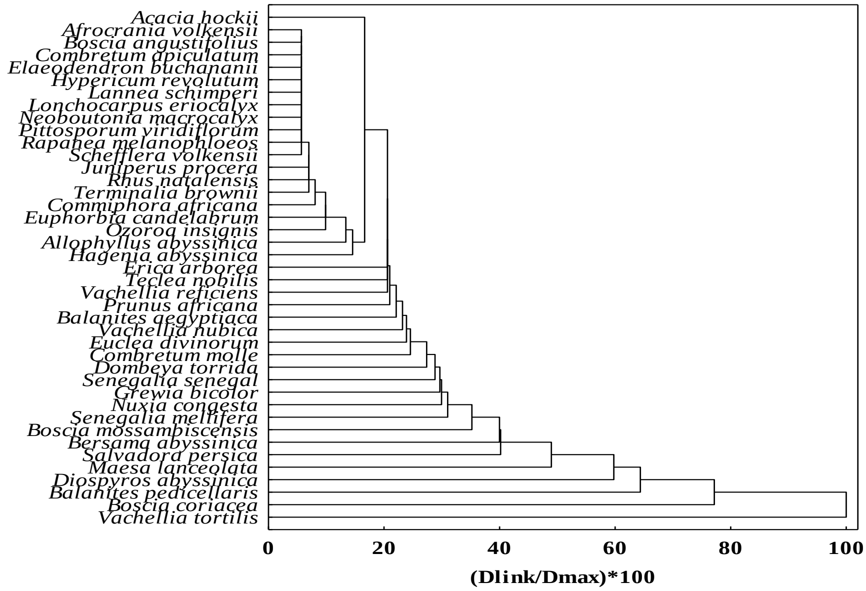

Figure 3: Cluster for Distribution of Tree in terms of Abundance.

The diversity of the tree species was also determined for the studied area (Figure 4). The montane region had the highest species diversity followed by escarpment and the least abundant region was the valley floor.

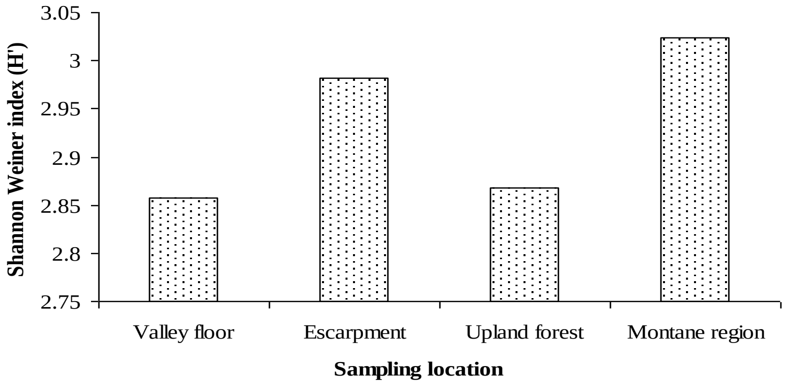

Figure 4: Shannon Weiner Diversity of the Tree Species in Embobut Basin.

DISCUSSION

Several studies have been undertaken to understand the tree diversity in the Kenyan forest ecosystems with little on the tree species composition, abundance and diversity in small, human impacted forests. In the current study, Embobut River Basin had 41 tree species belonging to 24 families which is lower than the number of species in other tropical rainforest environments including 77 in Nandi Forest (Tanui & Saina, 2015), 121 Mt. Elgon Forest (Okello *et al*., 2010), 124 in Kakamega forest (Mitchell & Bleher, 2004), 102 in West Kenyan Rainforest (Lung & Schaab, 2006), but higher than that of 38 in Taita Hill (Rogo & Oguge, 2000; Pellikka *et al*., 2009). The low number of species than other tropical rainforest within the same region could be a sign of human activities, which are likely to reduce the diversity of species for various human needs (Lindenmayer & Fischer, 2013). It is also possible to attribute the species counts to unprotected status of the forest mainly because a comparison of the species count in this forest with unprotected forests in Kenya such as Mt. Elgon, South Nandi, Mau Forest, indicates that the number of species in the unprotected forests rarely exceeds 200.

In terms of distribution, the study established that the valley floor had the highest frequency of tree (16) followed by escarpment (15), then uplands (9) and least in montane (8). No single species occurred at all sampling sites. The valley flow was dominated by species in Capparaceae (*Boscia angustifolius*, *Boscia coriacea*, *Boscia mossambiscensis*) and Fabaceae (*Senegalia mellifera*, *Senegalia senegal*, *Vachellia nubica*, *Vachellia reficiens* and *Vachellia tortilis*) which could be associated with aggressiveness of these species and ability to colonize different habitats and survive in areas that are not perfect for plant growth (Báez and Homeier, 2018). In the escarpment the dominant species belonged to family Anacardiaceae (*Lannea schimperi* and *Ozoroa insignis*), Combretaceae (*Combretum apiculatum* and *Combretum molle*), Ebenaceae (*Diospyros abyssinica* and *Euclea divinorum*), different species of family Fabaceae (*Acacia hockii*, *Lonchocarpus eriocalyx*, *Senegalia mellifera*) which can grow and survive well in areas with less human interference as was observed during the study. There was no dominance of any family in the upland forest and montane region but occurrence of single specialized species within the region. Single species dominance within the montane forest was also observed which compares with other studies in Mt. Elgon (Okello *et al*., 2010), Nandi Forest (Tanui & Saina, 2015), Arabuko Sokoke Forest (Muriithi & Kenyon, 2002) and Taita Hills Forest (Pellikka *et al*., 2013) all in Kenya and in Brazilian Atlantic rainforest (Scarano, 2002), in which, most families and genera were also represented by single species.

CONCLUSION

In conclusion, the species distribution in terms of presence/absence and abundance was determined using cluster analysis. The results showed that there were 41 tree species belonging to 24 families. The valley floor had the highest frequency of tree (16) followed by escarpment (15), then uplands (9) and least in montane (8). No single species occurred at all site probably due to high degree of specialization in their endemic ecological zone. Few species such as *Vachelia tortilis*, *Sengalia meliffera*, *Boscia coriacea*, *Bersama abbysinica* and *Balanites pedicellaris* showed wide distribution in terms of composition and abundance beyond their native habitats. The montane region had the highest species diversity followed by escarpment and the least abundant region was the valley floor. Some of the areas within the forest showing signs of relatively little human impacts can be designated for strict conservation so that they may act as repositories of biodiversity and possibly as a source of forest genetic resources, alongside sustainable use of the already exploited forest. Conserving ecological systems, plant communities, and species provide a more ecologically integrated conservation strategy. Conservation, in order to be effective, must strive to balance the protection of countable objects of diversity and the use of natural processes, the balance which should entail a broad assortment of programs on a variety of spatial and organizational scales.

IMPLICATIONS FOR CONSERVATION

The lowland forests have the highest species diversity, while the forests in the montane zone have the lowest. Within each zone, the variation in Shannon-Wiener’s index between forest types declines. Rank-abundance diagrams show the presence of many rare species in all the communities, but a higher proportion in the lowlands.

Both the tree species diversities and the number of genera and families are higher in the middle montane and lowland forests than in the lower montane. The lower species diversity and the predominance of Fabaceae in these lower montane forests suggest that they could be largely secondary. Conservation should focus on the species-rich valley floor where there is large number of settlements.

REFERENCES

Asfaw, A. G. (2018). Woody Species Composition, Diversity and Vegetation Structure of Dry Afromontane Forest, Ethiopia. *Journal of Agriculture and Ecology Research International, 16(3),* 1-20.

Awoke, H. & Mewded, B. (2019). Changes in woody species composition and structure of Denkoro dry evergreen Afromontane forest over 16 years (2001–2017), South Wollo, Ethiopia. *Forest Ecology and Management, 441,* 71-79.

Aynekulu, E., Aerts, R., Denich, M., Negussie, A., Friis, I., Demissew, S. & Boehmer, H.J. (2016). Plant diversity and regeneration in a disturbed isolated dry Afromontane forest in northern Ethiopia. *Folia geobotanica, 51,* 115-127.

Báez, S. & Homeier, J. (2018). Functional traits determine tree growth and ecosystem productivity of a tropical montane forest: Insights from a long-term nutrient manipulation experiment. *Global change biology, 24,* 399-409.

Bett, M. C., Muchai, M. & Waweru, C. (2017). Effects of human activities on birds and their habitats as reported by forest user groups in and around North Nandi Forest, Kenya. *Scopus: Journal of East African Ornithology, 37,* 24-31.

Bogale, T., Datiko, D. & Belachew, S. (2017). Structure and natural regeneration status of woody plants of berbere afromontane moist forest, bale zone, South East Ethiopia; implication to biodiversity conservation. *Open Journal of Forestry, 7,* 352.

Busck-Lumholt, L. & Treue, T. (2018). Institutional challenges to the conservation of Arabuko-Sokoke Coastal Forest in Kenya. *International Forestry Review, 20,* 488-505.

Chebet, C., Odenyo, V. A. & Kipkorir, E. C. (2017). Modeling the impact of land use changes on river flows in Arror watershed, Elgeyo Marakwet County, Kenya. *Water Practice and Technology, 12,* 344-353.

Chirchir, E., Sudoi, V. & Kimanzi, J. (2018). Impacts of Forest Disturbance on Food Trees of Colobus angolensis in Kibonge Forest, Kenya. *Africa Environmental Review Journal, 3,* 82-93.

Gadow, K. V., Zhang, G., Durrheim, G., Drew, D. & Seydack, A. (2016). Diversity and production in an Afromontane Forest. *Forest Ecosystems, 3,* 15.

Jones, K. R., Venter, O., Fuller, R. A., Allan, J. R., Maxwell, S. L., Negret, P. J. & Watson, J. E. (2018). One-third of global protected land is under intense human pressure. *Science, 360,* 788-791.

Los, S. O., Street-Perrott, F. A., Loader, N. J., Froyd, C. A., Cuní-Sanchez, A. & Marchant, R. A. (2019). Sensitivity of a tropical montane cloud forest to climate change, present, past and future: Mt. Marsabit, N. Kenya. *Quaternary Science Reviews, 218,* 34-48.

Malanson, G. P., Resler, L. M., Butler, D. R. & Fagre, D. B. (2019). Mountain plant communities: Uncertain sentinels? *Progress in Physical Geography: Earth and Environment.* 0309133319843873.

Mandela, H. K., Tsingalia, M. H., Gikungu, M. & Lwande, W. M. (2018). Distance Effects on Diversity and Abundance of the Flower Visitors of Ocimum kilimandscharicum in the Kakamega Forest Ecosystem. *International Journal of Biodiversity*. vol. 2018, Article ID 7635631, 7 pages, 2018. https://doi.org/10.1155/2018/7635631.

McGlinn, D. J., Xiao, X., May, F., Gotelli, N. J., Engel, T., Blowes, S. A., Knight, T. M., Purschke, O., Chase, J. M. & McGill, B. J. (2019). Measurement of Biodiversity (MoB): A method to separate the scale-dependent effects of species abundance distribution, density, and aggregation on diversity change. *Methods in Ecology and Evolution, 10,* 258-269.

Muhati, G. L., Olago, D. & Olaka, L. (2018). Participatory scenario development process in addressing potential impacts of anthropogenic activities on the ecosystem services of Mt. Marsabit forest, Kenya.

Global ecology and conservation, 14, e00402.

Mutoko, M. C., Hein, L. & Shisanya, C. A. (2015). Tropical forest conservation versus conversion trade-offs: insights from analysis of ecosystem services provided by Kakamega rainforest in Kenya. *Ecosystem services, 14,* 1-11.

Ndang'ang'a, P. K., Barasa, F. M., Kariuki, M. N. & Muoria, P. (2016). Trends in forest condition, threats and conservation action as derived from participatory monitoring in coastal Kenya. *African journal of ecology, 54,* 76-86.

Niu, Y., Yang, S., Zhou, J., Chu, B., Ma, S., Zhu, H. & Hua, L. (2019). Vegetation distribution along mountain environmental gradient predicts shifts in plant community response to climate change in alpine meadow on the Tibetan Plateau. *Science of the Total Environment, 650,* 505-514.

Njue, N., Koech, E., Hitimana, J. & Sirmah, P. (2016). Influence of land use activities on riparian vegetation, soil and water quality: An indicator of biodiversity loss, South West Mau Forest, Kenya. *Open Journal of Forestry, 6,* 373.

Norberg, A., Abrego, N., Blanchet, F. G., Adler, F. R., Anderson, B. J., Anttila, J., Araújo, M. B., Dallas, T., Dunson, D. & Elith, J. (2019). A comprehensive evaluation of predictive performance of 33 species distribution models at species and community levels. *Ecological Monographs,* e01370.

Pek, J., Wong, O. & Wong, A. (2018). How to Address Non-normality: A Taxonomy of Approaches, Reviewed, and Illustrated. *Frontiers in psychology*, *9,* 2104.

Quaresma, A. C., Piedade, M. T. F., Wittmann, F. & Steege, H. (2018). Species richness, composition, and spatial distribution of vascular epiphytes in Amazonian black-water floodplain forests. *Biodiversity and conservation*, *27,* 1981-2002.

Reshad, M. & Beyene, M. M. (2019). Woody Species Richness and Diversity at Ades Dry Afromontane Forest of South Eastern Ethiopia. *American Journal of Agriculture and Forestry, 7,* 44-52.

Ribeiro-Oliveira, J. P., Santana, D. G., Pereira, V. J. & Santos, C.M. (2018). Data transformation: An underestimated tool by inappropriate use. *Acta Scientiarum. Agronomy*. *40*, e35300.

Schmitt, C. B., Kisangau, D. & Matheka, K. W. (2019). Tree diversity in a human modified riparian forest landscape in semi-arid Kenya. *Forest Ecology and Management, 433,* 645-655.

Seta, T., Demissew, S. & Woldu, Z. (2019). Floristic diversity and composition of the Biteyu forest in the Gurage mountain chain (Ethiopia): implications for forest conservation. *Journal of forestry research, 30,* 319-335.

Siyum, Z. G., Ayoade, J., Onilude, M. & Feyissa, M. T. (2019). Climate forcing of tree growth in dry Afromontane forest fragments of Northern Ethiopia: evidence from multi-species responses. *Forest Ecosystems, 6,* 15.

Soriano-Redondo, A., Jones-Todd, C. M., Bearhop, S., Hilton, G. M., Lock, L., Stanbury, A., Votier, S. C. & Illian, J. B. (2019). Understanding species distribution in dynamic populations: A new approach using spatio-temporal point process models. *Ecography, 42*(6), 1092-1102.