ANTHROPOGENIC INFLUENCES ON SPECIES COMPOSITION AND DIVERSITY DRYLAND FOREST FRAGMENTS KITUI EASTERN KENYA

J.M. Musau and M.J. Mugo
Karatina University, School of Environmental Studies and Natural Resources Management
P.O. Box 1957- 10101, Karatina.

ABSTRACT

Increase in human population has devastating effects on many dryland forest fragments in Eastern Kenya. The objectives of this paper are to determine (*i*) key human activities in Kitui dryland forest fragments, (*ii*) tree species composition and (iii) impact of human activities on tree species composition and diversity. Two belt transect of 20 m wide and 500 m long that employed use of nested sample plots of 20 m ×20 m, sub-plots of 10 m ×10 m and micro-plots of 2 m ×5 m were established in each forest. Human activities occurred in both forests but with high frequency (P<0.05) in Museve. Introduction of exotic species boosted species composition in Museve forest recording 68 species compared to Mutuluni with 57 species. However, it altered species dominances in Museve with *Eucalyptus saligna* (SIV = 16.77%), an exotic species being most dominant and reduced species similarity (JI_A = 0.37) across the two forests. Tree cutting reduced (P<0.05) species richness and diversity in Museve which recorded lower Shannon Diversity Index (H'=1.46) compared to Mutuluni (H'=1.50). Thus, this study concludes that human activities affected species composition in both forests with Museve forest most disturbed. It thus recommends improved conservation measures for both forest reserves with most attention on Museve and further research on consequences of altering species dominance by *Eucalyptus saligna* in Museve forest.

Keywords: Human activity, species composition, diversity, dominance, richness, fragments

INTRODUCTION

Forest ecosystems provide key regulative, provisional, cultural and supportive ecosystem services essential for conservation of the biodiversity of species and eco-system (Millennium Ecosystem Assessment -MEA, 2005. However, these ecosystems require sound conservation measures for adequate functioning and productivity which is highly anchored on integrity of their species composition, richness and diversity (Mutiso, *et al.,* 2015; Food and Agricutural Organization (FAO), 2010).

Destructive human activities such as deforestation, over grazing, over-exploitation, introduction of invasive species, pollution and climate change have significantly impacted tree species composition, richness and diversity in global forest ecosystems especially within the tropics (Obiri, 2011; Morris, 2010; Mahbud, 2008). Studies by Gonzalez (2001) and MEA (2005) have indicated that the biodiversity of species is on decline due to human activities. As a result, more fragile ecosystems, unsustainable livelihoods and fragile local and national economies are the manifest in the drylands affected areas (Ochola *et. al*., 2010; Mathu, 2011; Middleton and Thomas, 1997).

Arid and Semi-Arid Lands (ASALs) are all times fragile and more vulnerable ecosystems to degradation (FAO, 2010; Kenya Forestry Service (KFS), 2012). Consequently, uncontrolled human activities has resulted into widespread fragmentation of forest cover (Kigomo, 2003). Most of forest cover in drylands is concentrated around hilltops and/or conservation reserves, where they provide necessary ecosystem services in these areas (United Nations Environment Programme -UNEP, 2007). These hilltops form key water catchment areas, hold unique life forms and are important habitats essential to the long-term maintenance of biodiversity and other natural processes in the drylands (Gachathi, 2012).

Nevertheless, not much is known about tree species

*Corresponding author: jmware@karu.ac.ke

composition and diversity of these dryland forests fragments (Gachathi, 2012). Consequently, many forest fragments in drylands like Museve and Mutuluni forests are under threat from human activities by the surrounding human population. Extent and severity of human influences in these hilltop forest fragments are not known, a case that requires immediate attention. The lack of information on how human activities impact on sustainable use of forestry resources in hill top forests hinder sustainable use of these resources.

The objectives of this paper are to determine (*i*) key human activities in Kitui dryland forest fragments, (*ii*) r tree species composition and (*iii*) impact of human activities on tree species composition and diversity.

MATERIALS AND METHODS

Study area

The study was undertaken at Museve (1.3272° S, 38.0737° E) and Mutuluni (2.0167° S, 38.2833° E) forest fragments (Figure 1). Museve forest fragment (48 ha) and Mutuluni forest fragment (596 ha) are located in Kitui Central (667 km^2) and Kitui East Constituencies (5,119.7 km^2) respectively; Kitui County (Kenya National Bureau of Statistics (KNBS), 2010; MENR and Belgian Technical Cooperation (BTC), 2002). The area receives an annual average rainfall ranging from 750 mm to 1150 mm distributed in two rainy seasons. Temperatures ranges from a minimum of 15.7^{o}C to a maximum of 27.1^{o}C annually while the geology mainly consists of sedimentary plains which are usually low in natural (MENR, 1994; Ministry of Agriculture (MoA), 1983). Both forest fragments are state owned secondary forests previously owned by local communities before colonial era (Mbuvi *et al.,* 2010). Since then, Mutuluni forest has been left to recover naturally while Museve forest has undergone several human interventions including introduction of exotic tree species by forest management which failed due to ecological conditions (Mbuvi *et al.,* 2010).

Sampling design and data collection

Belt transects of 500 m × 20 m wide that employed use of nested sampling plots was the main study design. Two belt transects were longitudinally established in each forest. The highest elevation guided the choice of start point for transect 1 which run on 1 direction. To separate the 2 transects, a distance of 50 m from the start point on the opposite direction was marked as the start point for transect 2 which run on the opposite direction. In each transect, main plots measuring 20 m × 20 m were established which were further sub-divided into subplots measuring 10 m × 10 m and microplots measuring 2 m ×5 m.

In the main plots, data on evidences of human activities and on mature trees were collected. Evidences of the predetermined indicators of human activities were signs of charcoal burning, pit sawing, footpaths, grazing, fire, debarking, grass cutting, tree cutting and presence of exotic trees.Plant growth characteristics were used to identify and to distinguish trees from other forms of vegetation. A maximum height of 5 m at maturity criteria was used to distinguish trees from shrubs. The trees were identified and diameter measured at breast height (dbh) for mature trees (≥ 5cm dbh). In the sub-plots, data on saplings (trees 1cm ≥ dbh <) was collected while in the microplots seedlings were identified and counted.

Data analyses

Incidences of human activities were summarized into a frequency table indicating number of plots in which the incidences occurred.A two-sided test of equality for column proportions using z-test was done. To assess intensity of tree cutting, the number of trees cut per plot was converted into stems per hectare (Equation 1); explored for deviation from normality and compared within and between the two forests using student *t*-test and Mann-Whithey test statistics at 95% level of significance.

Stems/ha = Number of trees/Area(Ha) (1)

All trees, seedlings, saplings and mature individuals in both forests were listed and identified by their families, genus and species to capture the composition of forest. Botanical guides as as described in by Maundu and Bo Tengnas (2005) and Beentje (1994) were used for species identification. Further identification by aid of taxonomist was also done at Kenya Forestry Research Institute (KEFRI)

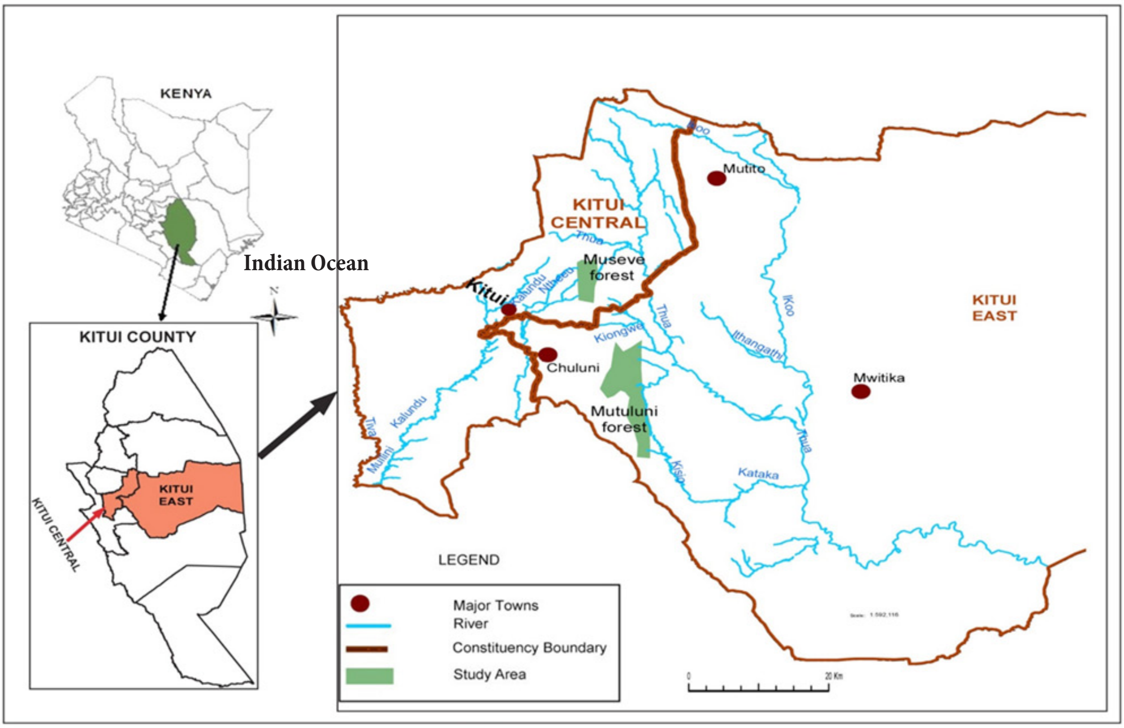

Figure 1. Experimental site at Museve and Mutuluni forest fragments in Kitui County Eastern Kenya.

Kitui and Muguga Centres. The Jaccard similarity coefficient (Kentand Corker, 1992) and Species Importance values (SIV) as cited by Kacholi (2014) were calculated using Equations 2 and 3, respectively to examine species similarity and species ecological importance respectively between the 2 forests.

Jaccard's index (JI_A) = a / (a+b+c) (2)

Where,

a - Number of species common in Museve and Mutuluni forests

b - Number of species in Museve but not Mutuluni forest

c - Number of species in Mutuluni but not Museve forest

SIV = Rf + RDe + RDo (3)

Where,

Rf – Species Relative Frequency

RDe – Species Relative Density

RDo – Species Relative Dominance

Calculated SIV were ranked from the largest to the smallest in each forest for assessment and the most ten important species identified.

Tree species diversity indices were computed (Equation 4) for each 20 m ×20 m plot using Shannon-Weiner diversity index (Harris, 1983).

$$\mathbf{H}' = -\sum_{i=1}^{R} pi\ lnpi \quad (4)$$

Where;

H' -Shannon Diversity Index,

pi- Proportion of individuals of species belonging to the ith species in the data set of interest

The Shannon-Weiner's index was most preferred because it provides an account of both the abundance and evenness and does not unreasonably favour one species (Omoro, 2012).

The derived Shannon's diversity indices were further converted into effective numbers (Equation 5) to compare trees species diversity within and between the two forests. According to Lou (2006), effective number of species is the true diversity of the community in question and is simply the number of equally-common species required to give a particular value of an index;

$$\mathit{Effectives\ Numbers} = \mathit{Exp}(H') \qquad (5)$$

Where H' -Shannon Diversity Index,

Species richness (S) was also done at every 20m ×20m plot by counting the number of species present. The following equation (Equation 6) as cited by Omoro(2012) was applied.

$$\mathit{Species\ Richness}\ (S) = \sum n \qquad (6)$$

Where n is number of species in a plot.

Student t-test was used to compare tree species richness (S) and tree species diversity indices (H') within and between Museve and Mutuluni forests. Logistic regression was used to investigate the impacts of documented human activities in each forest. The human activities were regressed as independent predictor variables against the dependent variables tree species richness (S) and species diversity (H'), respectively. The model statistics and coefficients statistics were given in a summary table.

RESULTS

Types and prevalence of human activities in Museve and Mutuluni forest reserves

Only 5 indicators of human activities were observed in both Museve and Mutuluni forests. The activities were mainly presence of foot paths, grazing, debarking of trees, tree cutting and introduction of exotic species. Three of the indicators occurred in both forest while debarking and presence of exotic species occurred only in Mutuluni and Museve forest, respectively (Table I). A 2-sided test of equality for column proportions using z-test indicated significant ($P < 0.05$) differences in frequencies of presence of tree cutting, grazing and foot paths. The frequencies were higher in Museve forest compared to Mutuluni. Presence of exotic species and human and/or livestock tree debarking were not compared because they only occurred in either Museve or Mutuluni forest (Table I).The number of trees cut was also significantly ($P < 0.05$) higher in Museve forest than in Mutuluni. Moreover, within Museve forest the number of trees cut varied significantly ($P < 0.05$) whereas no significant ($P > 0.05$) difference was observed within Mutuluni forest.

TABLE I - TYPES AND FREQUENCIES OF HUMAN ACTIVITIES RECORDED IN MUSEVE AND MUTULUNI DRYLAND HILLTOP FOREST RESERVES.

Human activities		Forest		
			Museve forest	Mutuluni forest
		Count	Count	Count
Tree Cutting	0	$0^{1,2}$	3_a	23_b
	1	$0^{1,2}$	47_a	27_b
Grazing	0	$0^{1,2}$	18_a	40_b
	1	$0^{1,2}$	32_a	10_b
Human/livestock debarking	0	$0^{1,2}$	50^2	44_a
	1	$0^{1,2}$	0^2	6_a
Footpaths	0	$0^{1,2}$	20_a	38_b
	1	$0^{1,2}$	30_a	12_b
Exotic species	0	$0^{1,2}$	3_a	50^2
	1	$0^{1,2}$	47_a	0^2

Note: Values in the same row and subtable not sharing the same subscript are significantly different at p< .05 in the two-sided test of equality for column proportions. Cells with no subscript are not included in the test. Tests assume equal variances.

Tree species composition and species diversity

Tree species composition

A total of 68 tree species (seedlings, saplings and mature trees) belonging to 28 families were detected in Museve forest (Table II) while 57 tree species belonging to 31 families were observed in Mutuluni forest (Table III). However, the number of tree species for mature trees found in Mutuluni forest (52) was higher than that of Museve (48). In addition, More seedlings and saplings (regeneration composition) were found in Museve forest compared toMutuluni (Table III). This may imply that Museve is recovering from destruction due to human activities .

TABLE II. LIST OF TREE SPECIES FOUND IN MUSEVE FOREST RESERVE, KITUI COUNTY

Family name	Species name	Mature trees	Saplings	Seedlings
Mimosaceae	*Acacia hockii* De Wild.	√	√	√
Mimosaceae	*Acacia nilotica* L.	√	√	√
Mimosaceae	*Acacia polyacantha* Willd.	√	√	√
Mimosaceae	*Acacia Senegal* (L.) Willd.			√
Mimosaceae	*Acacia seyal* Delile.	√	√	√
Apocynaceae	*Acokanthera oppositifolia* (Lamarck) Codd.	√	√	√
Fabaceae	*Acrocarpus fraxinifolius* Arnold.		√	√
Mimosaceae	*Albizia anthelmintica* (L.) Benth.			√
Annonaceae	*Annona senegalensis* Pers.			√
Euphorbiaceae	*Antidesma venosum* Tul.	√	√	√
Malvaceae	*Azanza garckeana* F. Hoffm.	√	√	√
Euphorbiaceae	*Bridelia taitensis* Vatke & Pax ex Pax.	√	√	√
Rutaceae	*Calodendrum capense* (L.f.) Thunb.	√	√	
Apocynaceae	*Carissa spinarum* L.		√	√
Caesalpiniaceae	*Cassia abbreviate* Oliv.	√		
Combretaceae	*Combretum collinum* Fres.	√	√	√
Combretaceae	*Combretum molle* G.	√	√	√
Combretaceae	*Commelina benghalensis* L.		√	
Burseraceae	*Commiphora Africana*(A. Rich.) Engl.	√	√	√
Burseraceae	*Commiphora habesinica* Engl.		√	√
Euphorbiaceae	*Croton megalocarpus* Hutch.	√	√	√
Cupressaceae	*Cupressus lusitanica* Mill.	√	√	√
Papilionaceae	*Dalbergia melanoxylon* Guill. & Perr.	√	√	√
Mimosaceae	*Dichrostachys cinerea* (L.) Wight & Arn.	√	√	√
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A.DC.	√	√	√
Papilionaceae	*Erythrina abyssinica* Dc.	√	√	
Myrtaceae	*Eucalyptus grandis* W. Hill.	√		
Myrtaceae	*Eucalyptus paniculata* Sm.	√	√	
Myrtaceae	*Eucalyptus saligna* Sm.	√	√	√
Ebenaceae	*Euclea divinorum* Hiern.	√	√	√
Euphorbiaceae	*Euphorbia candelabrum* Trémaux ex Kotschy.	√		√
Rutaceae	*Fagara chelybeum* Engl.		√	√
Moraceae	*Ficus sycomorus* L.		√	
Moraceae	*Ficus thonningii* Blume.			√
Tiliaceae	*Grewia bicolor* Juss.	√	√	√
Proteaceae	*Grevillea robusta* A.Cunn. ex R.Br.	√	√	√
Umbelliferae	*Heteromorpha trifoliata (*H.L.Wendl.) Eckl. & Zeyh.		√	
Anacardiaceae	*Lannea schimperi* (Hochst. ex A.Rich.) Engl.			√

TABLE II. LIST OF TREE SPECIES FOUND IN MUSEVE FOREST RESERVE, KITUI COUNTY

Family name	Species name	Mature trees	Saplings	Seedlings
Anacardiaceae	*Lannea schweinfurthii* Engl.	√		
Anacardiaceae	*Lannea triphylla* (Hochst. ex A.Rich.) Engl.	√	√	
Capparaceae	*Maerua crassifolia* Forssk.	√	√	√
Anacardiaceae	*Mangifera indica* L.		√	√
Bignoniaceae	*Markhamia lutea* (Benth.) K.Schum.			√
Celastraceae	*Mystroxylon aethiopicum* (Thunb.) Loes.		√	√
Ochnaceae	*Ochna holstii* Engl.			√
Ochnaceae	*Ochna ovata* F. Hoffm.	√	√	√
Papilionaceae	*Ormocarpum kirkii* S. Moore.	√	√	√
Papilionaceae	*Ormocarpum trachycarpum* (Taub.) Harms.	√	√	
Santalaceae	*Osyris lanceolata* Hochst. & Steud.	√	√	√
Rubiaceae	*Pavetta gardeniifolia* Hochst. ex A. Rich.	√	√	√
Caesalpiniaceae	*Piliostigma thonningii* Schum.		√	√
Salicaceae	*Populus ilicifoilia* Engl.	√	√	√
Myrtaceae	*Psidium guajava* L.	√	√	√
Anacardiaceae	*Rhus natalensis* Bernh. ex C.Krauss.	√	√	√
Anacardiaceae	*Rhus vulgaris* Meikle.	√	√	√
Anacardiaceae	*Sclerocarya birrea* A.Rich.	√	√	
Caesalpiniaceae	*Senna siamea* Lam.	√	√	√
Caesalpiniaceae	*Senna singueana* Delile.	√	√	√
Caesalpiniaceae	*Senna spectabilis* (DC.) H.S.Irwin & Barneby.	√	√	√
Apiaceae	*Steganotaenia araliacea* Hochst.	√	√	√
Loganiaceae	*Strychnos decussata* Pappe.		√	√
Loganiaceae	*Strychnos spinosa* Lam.	√	√	
Euphorbiaceae	*Synadenium compactum* Var. rubrum S.Carter.	√	√	
Combretaceae	*Tamarindus indica* L.			√
Combretaceae	*Terminalia brownii* Fres.	√	√	√
Combretaceae	*Terminalia spinosa* Engl.	√	√	√
Rubiaceae	*Vangueria madagascariensis* J.F.Gmel.		√	
Verbenaceae	*Vitex payos* (Lour.) Merr.	√	√	√
Total		48	55	54

√ Indicates presence of the species at either maturity, sapling and/or seedling stage.

TABLE III - LIST OF TREE SPECIES IN MUTULUNI FOREST RESERVE, KITUI COUNTY.

	Family Name	Species Name	Mature Trees	Saplings	Seedlings
1	Mimosaceae	*Acacia nilotica* L.	√		
2	Mimosaceae	*Acacia polyacantha* Willd.	√		
3	Mimosaceae	*Acacia seyal* Delile.	√		
4	Mimosaceae	*Albizia anthelmintica* (L.) Benth.	√		
5	Mimosaceae	*Albizia gummifera* Gmel.	√		
6	Malvaceae	*Azanza garckeana* F. Hoffm.	√	√	√
7	Melianthaceae	*Bersama abyssinica* Fresen.	√	√	√
8	Capparaceae	*Boscia angustifolia* A. Rich.		√	√
9	Euphorbiaceae	*Bridelia taitensis* Vatke & Pax ex Pax.	√	√	√
10	Rutaceae	*Calodendrum capense* (L.f.) Thunb.	√	√	√
11	Apocynaceae	*Carissa spinarum* L.	√	√	
12	Rhizophoraceae	*Cassipourea celastroides* Alston.	√	√	
13	Combretaceae	*Combretum collinum* Fres.	√	√	√
14	Combretaceae	*Combretum molle* G.	√	√	√
15	Burseraceae	*Commiphora Africana* (A. Rich.) Engl.	√	√	√
16	Burseraceae	*Commiphora eminii* Engl.	√		√
17	Burseraceae	*Commiphora habesinica* Engl.	√	√	
18	Burseraceae	*Commiphora spp.*	√		
19	Boraginaceae	*Cordia monoica* Roxb.	√	√	√
20	Euphorbiaceae	*Croton megalocarpus* Hutch.	√	√	√
21	Papilionaceae	*Dalbergia melanoxylon* Guill. & Perr.	√	√	√
22	Mimosaceae	*Dichrostachys cinerea* (L.) Wight & Arn.	√	√	
23	Ebenaceae	*Diospyros mespiliformis* Hochst. ex A.DC.	√	√	√
24	Salvadoraceae	*Dobera glabra* (Forssk.) Juss. ex Poir.	√		
25	Sterculiaceae	*Dombeya burgessiae* Gerrard ex Harv.	√	√	√
26	Ebenaceae	*Euclea divinorum* Hiern.	√	√	√
27	Euphorbiaceae	*Euphorbia tirucalli* L.		√	√
28	Moraceae	*Ficus glumosa* Del.	√		√
29	Moraceae	*Ficus thonningii* Blume.	√	√	√
30	Flacourtiaceae	*Flacourtia indica* (Burm. f.) Merr.	√	√	
31	Tiliaceae	*Grewia bicolor* Juss.	√	√	√
32	Rutaceae	*Harrisonia abyssinica* Oliv.	√	√	
33	Anacardiaceae	*Lannea schweinfurthii* Engl.	√	√	√
34	Anacardiaceae	*Lannea triphylla* (Hochst. ex A.Rich.) Engl.	√	√	√
35	Fabaceae	*Lonchocarpus eriocalyx* Harms.	√	√	√
36	Celastraceae	*Maytenus obscura* (A. Rich.) Cufod.	√	√	√
37	Celastraceae	*Mystroxylon aethiopicum* (Thunb.) Loes.	√	√	

TABLE III - LIST OF TREE SPECIES IN MUTULUNI FOREST RESERVE, KITUI COUNTY.

	Family Name	Species Name	Mature Trees	Saplings	Seedlings
38	Ochnaceae	*Ochna ovata F. Hoffm.*	√	√	√
39	Papilionaceae	*Ormocarpum kirkii* S. Moore.	√	√	
40	Santalaceae	*Osyris lanceolata* Hochst. & Steud.			√
41	Sapindaceae	*Pappea Capensis* Eckl. & Zeyh.	√	√	
42	Rubiaceae	*Pavetta gardeniifolia* Hochst. ex A.Rich.	√	√	√
43	Salicaceae	*Populus ilicifoilia* Engl.	√	√	√
44	Anacardiaceae	*Rhus natalensis* Bernh. ex C.Krauss.	√	√	
45	Anacardiaceae	*Rhus vulgaris* Meikle.	√	√	√
46	Anacardiaceae	*Sclerocarya birrea* A.Rich.	√		
47	Apiaceae	*Steganotaenia araliacea* Hochst.	√	√	
48	Loganiaceae	*Strychnos henningsii* Gilg.	√	√	√
49	Loganiaceae	*Strychnos madagascariensis* Poir.			√
51	Caesalpiniaceae	*Tamarindus indica* L.	√		
52	Rutaceae	*Teclea nobilis* Delile.	√	√	√
53	Combretaceae	*Terminalia brownii* Fres.	√	√	√
54	Combretaceae	*Terminalia spinosa* Engl.		√	
55	Rubiaceae	*Vangueria madagascariensis* J.F.Gmel.	√	√	√
56	Rutaceae	*Zanthoxylum chalybeum* Engl.	√		
57	Rhamnaceae	*Ziziphus abyssinica*Hochst. ex A.Rich.	√	√	√
	Total		**52**	**43**	**31**

√ Indicates presence of the species at either maturity, sapling and/or seedling stage**.**

Species similarities

The computed Jaccard similarity coefficient (JI_A) between Museve and Mutuluni forest was 0.37. According to Marimon and Felfili (1997) this is below the critical value of $JI_A = 0.5$ indicating that tree species composition in Museve and Mutuluni forest were not similar. Likewise, tree species composition within Mutuluni forest reserve were heterogenous , with JI_A of 0.48. However, Museve forest consisted of similar species with JI_A of 0.67.

Species dominance and importance values

At Museve, SIV of 53.5% was observed (Table IV) and 10 most dominant tree species observed were *Eucalyptus saligna* Sm*, Azanza garckeana* F. Hoffm.*, Combretum molle* G.*, Euclea divinorum* Hiern. *Antidesma venosum* Tul. *Dichrostachys cinerea* (L.) Wight & Arn.*, Erythrina abyssinica* Dc, *Commiphora africana* (A. Rich.) Engl., *Terminalia brownii* Fres. and *Calodendrum capense* (L.f.) Thunb In Mutuluni forest, SIV of 58.58% was detected (Table IV) and . the 10 most predominat species in this Forest were *Teclea nobilis* Delile*, Bersama abyssinica* Fresen.*, Croton megalocarpus* Hutch.*, Grewia bicolor* Juss*, Dombeya burgessiae* Gerrard ex Harv.*, Terminalia brownii* Fres.*, Diospyros mespiliformis* Hochst. ex A. DC., *Bridelia taitensis* Vatke & Pax ex Pax.*, Combretum collinum* Fres. and *Euclea divinorum* Hiern. Therefore, in both forests the most dominant species, which were less than 20 % of all observed species in each forest, exhibited a dominance value greater than 50%.

TABLE IV - SUMMARY OF THE TEN MOST DOMINANT SPECIES IN MUSEVE AND MUTULUNI FORESTS

	Museve forest		Mutuluni forest	
No.	**Species name**	**SIV %**	**Species name**	**SIV %**
1	*Eucalyptus saligna*Sm.	16.77	*Tecleanobilis*Delile	9.88
2	*Azanza garckeana*F. Hoffm.	7.31	*Bersama abyssinica*Fresen.	8.90
3	*Combretummolle*G.	5.28	*Croton megalocarpus*Hutch.	6.42
4	*Eucleadivinorum*Hiern.	4.93	*Grewiabicolor*Juss.	6.02
5	*Antidesmavenosum*Tul.	4.18	*Dombeyaburgessiae*Gerrard ex Harv.	5.95
6	*Dichrostachyscinerea*(L.) Wight & Arn.	3.91	*Terminalia brownii*Fres.	4.76
7	*Erythrinaabyssinica*Dc.	3.25	*Diospyrosmespiliformis*Hochst. ex A.DC.	4.70
8	*Commiphora Africana*(A. Rich.) Engl.	3.12	*Brideliataitensis* Vatke & Pax ex Pax.	4.56
9	*Terminalia brownii* Fres.	2.41	*Combretumcollinum*Fres.	3.71
10	*Calodendrumcapense*(L.f.) Thunb.	2.35	*Eucleadivinorum* Hiern.	3.68
	Total	**53.51**		**58.58**

Species richness and diversity

The mean diversity index for Mutuluni forest was 1.50 while Museve forest was 1.46 equivalent to effective number of species 5 and 4 for Mutuluni and Museve, respectively. A normality test indicated that diversity indices in the 20m ×20m plots for both Museve and Mutuluni forest deviated from normal distribution (D (50) = 0.36 P<0 .05) in Museve and (D (50) = 0.32 P< 0.05) in Mutuluni forest, respectively. Further, Mann-Whitney statistics revealed no significant differences (P> 0.05) in tree species diversity across the two forest reserves but it varied (P< 0.05) within each forest. Tree species richness in Museve forest were normally distributed (D (50) = 0.12 P> .05) whereas in Mutuluni they deviated (D (50) = 0.15 P< .05) significantly from normal distribution. Mann-Whitney test revealed there was not significant (P> 0.05) difference in species richness between the two forests but it varied within Mutuluni. However, within Museve forest species richness did not vary (t = 1.80, P> 0.05) significantly.

Impacts of human activities on tree species richness and diversity in 2 in the forest reserves

When tree cutting, presence of grazing, foot paths, tree debarking and exotic species was regressed against species richness and diversity, the likelihood *chi-* square statistics for logistic regression for species richness ($\chi 2$ = 5.75, df = 4, P> 0.05) and diversity ($\chi 2$ = 5.92, df = 4 P> 0.05) in Mutuluni forest were not significant. However, in Museve forest species richness (χ^2 = 29.77, df = 4, P< 0.05) and species diversity (χ^2 = 30.20, df = 4, P< 0.05) revealed significant differences. Thus human activities documented in Museve influenced species richness and diversity while in Mutuluni they did not have significant influence.

Test of parameters estimates indicated that only tree cutting significantly influenced tree species richness and diversity in Museve forest. Regression coefficients for tree cutting (b < -0.01, Wald χ^2 = 30.00, P> 0.05) on diversity and (b < -0.01, Wald χ^2 = 26.95, P> 0.05) on species richness were significantly different from 0 (Table V). It is therefore clear that tree cutting of trees reduced richness of species and diversity in Museve forest. Wald $\chi 2$ statistics for grazing, footpaths and introduction of exotic species were not significant (P > 0.05) implying that their occurrences did not influence the impacts on species richness and diversity in Museve forest (Table 5).

TABLE: V -TEST OF PARAMETER ESTIMATES FOR SPECIES RICHNESS AND DIVERSITY IN MUSEVE FOREST.

Dependent Variable	Parameter	B	Hypothesis Test		
			Wald Chi-Square	df	Probability
Diversity	(Intercept)	0.98	53.09	1	0.00
	Grazing	-0.02	0.05	1	0.82
	Footpaths	-0.09	0.66	1	0.42
	Trees cut/ha	-0.004	30.00	1	0.00
	No. Exotic species/ha	<0.00	2.60	1	0.11
Richness	(Intercept)	2.34	267.86	1	0.00
	Grazing	0.02	0.03	1	0.87
	Footpaths	-0.10	0.69	1	0.41
	Treescut/ha	<-0.01	26.95	1	0.00
	No. Exotic species/ha	<0.00	0.24	1	0.62

DISCUSSION

Presence of human activities were evident in both Museve and Mutuluni forest reserves. However, the frequencies and intensity of human activities was high in Museve forest compared to Mutuluni forest. A two-sided z-test for equality of column proportions revealed significant differences in presence of foot paths, cutting of trees and grazing between the 2 forests. The interference with the forest structure could be attributed to the fact that proximity of Museve forest to Kitui which has high surrounding human population. compared to Mutuluni (KNBS, 2010). It is expected that the nearby people exerted more human influence on the forest. Mbuvi *et al.* (2010) noted that much of the fuelwood for cooking and brick kilning in the area were derived from the surrounding forest reserves.

Of the five anthropogenic activities observed in Museve and Mutuluni forest, only introduction of exotic species and tree cutting which affected tree species composition, richness and diversity significantly. Introduction of exotic species in Museve forest resulted to high species richness and composition (68 species) in the forest compared to that of Mutuluni forest (57 species). Museve forest has experienced reafforestation programmes that targeted deliberate introduction of species not indigenous to the forest which are likely to enhance species composition (Mbuvi *et al*., 2010). It was observed that, all the eight remnant exotic species detected in Museve forest were absent in Mutuluni forest. According to Sovu (2011), introduction of tree species in areas where they were completely lacking enhances species composition, competition and richness of the receiving ecosystems.

The remnant exotic tree species were present in all development stages (seedlings, saplings and mature trees) indicating that they have integrated very well with the natural regeneration. Similar findings were reported where such integrations enhanced tree species composition in Taita Hills (Omoro *et al.,* 2010). In this study, presence of footpaths and grazing was higher in Museve forest compared to Mutuluni forest and this may have resulted from high edge effects. Omoro (2012) and Mutiso *et al.* (2015) noted that people and livestock movement in a forest may facilitated movement of plant propagules from the surrounding farmlands into the forest, thereby increasing species richness and composition, consequently, enriching tree species richness in Museve forest. This was vindicated by documentation of some fruit trees (*Psidium guajava* L. and *Mangifera indica L.*) in Museve forest which are usually domestic fruit trees in the study area (Table 2). Furthermore, the regeneration (seedlings and saplings) composition for Museve forest was higher compared to mature trees compared to

Mutuluni and this may be due to increased edge effects in Museve forest.

Results indicated that cutting of trees significantly reduced richness of species and diversity in Museve forest while no significant impacts were evident in Mutuluni. This is attributed to high intensity of tree cutting exhibited in Museve forest compared to Mutuluni. As a result, calculated Shannon-Wiener species diversity index for Museve forest (1.46) was lower compared to that of Mutuluni forest (1.50). Studies, Hitimana (2000) and Omeja *et al.* (2004) report that continued selective cutting of socio-economic tree species affect their regeneration and consequently species richness and diversity of a forest ecosystem. This is also in line with the findings that tree cutting particularly for fuelwood in ASALs is a major driver to to land cover change and degradation in drylands (Kiruki *et al.,* 2016; Kigomo, 2003).

Human activities influenced species dominances in the two forest fragments. The 10 most dominant tree species varied across the 2 forest reserves despite sharing similar ecological conditions. As a result of species introduction, *Eucalyptus saligna* Sm. a remnant exotic species was the most dominant (SIV=16.77%) in Museve forest. It is worth noting that eucalyptus spp. have high coppicing ability, exhibit rapid biomass input and are known to exudate allelopathic chemicals that may inhibit undergrowth of other species (KFS, 2009). This study therefore suggest that eucalyptus specie is able to maintain its presence and dominance in the forest continuum. The findings are also supported by Mutiso *et al*. (2013) and Obiri (2011) who shares that alien species may outcompete and substantially alter the gene pool of local plant materials thereby establishing their dominance and consequently influencing ecosystem functioning. The most dominant species are critical because they are known to influence ecosystem functioning most (Hitimana, 2000).Therefore, dominance of an exotic species in Museve forest is likely to interfere with the ecosystem functioning. Worse even, there is an increasing concern on the effect of *Eucalyptus spp* on the hydrological cycle and biodiversity conservation (KFS, 2009). On the contrary, Mutuluni forest did not have exotic tree species. As a result an indigenous species; *Teclea nobilis* Delile was the most dominant (SIV=9.88%) in the forest.

The widespread tree cutting in both forest reserves may have resulted into low calculated SIV of most species in both forests. Based on the SIV values, few (10) species represented high proportion (>50%) dominance in each forest (SIV >50%). Though, this is common with most tropical forest, it is an indication that most trees species were rare rather than common, hence the risk of local species extinction (Kacholi, 2014;Njunge and Mugo, 2011). Therefore, there is an urgent need for increased conservation efforts in both forests. Kacholi (2014) and Omeja *et al.* (2004) suggested that, over utilization of rare species or those species with social-economic value can result to their local extinction.

Human activities also influenced species composition across the 2 forests. The two forests share same ecological zone and experience similar climatic conditions, thus it would be expected that tree species composition across the two forests would be similar. This was not the case as the two forests exhibited low species similarities. This can be explained by exotic species in Museve forest resulting to different species composition from that of Mutuluni. Also, Museve forest documented high frequencies of human activities like grazing and footpaths that may increase the likelihood of introducing propagules of other tree species from the surrounding farmlands into the forest (Mutiso *et al.,* 2013; Omoro, 2012;). This could have led to reducing similarity of species composition across the two forests. Besides, selective tree cutting is known to affect tree species composition (Kacholi, 2014; Hitimana *et al*., 2004). Thus, widespread selective tree cutting in both forests and may have resulted into unequal influences on species similarities across the two forests

It is also worth noting that low species similarity across the two forests implies that, each forest has certain tree species unique from each other (Kacholi, 2014). Hence, the need to conserve and protect each forest to minimise risks of local species extinction posed by threats from documented human activities. The high species similarity Index ($JI_A = 0.67$) within

Museve forest may imply that similar tree species have been introduced throughout the forest. On the other hand similarity Index (JI_A = 0.48) for Mutuluni indicated low similarity in species composition. Hitimana (2000) and Mutiso *et al*. (2015) have also shown low species similarity within the same forest as it was the case for Mutuluni forest.

Conclusion and Recommendations

Only 5 out of the 9 predetermined human activities were documented in Museve and Mutuluni forest reserves with high occurrences in Museve. Tree cutting and introduction of exotic tree species impacted tree species richness, diversity and composition the most. Presence of grazing, foot paths and tree debarking did not necessarily result into significant impacts.

Introduction of exotic species in Museve forest reserve increased species richness in Museve but resulted to low similarity in species composition across the two forests. Species dominances were also affected in Museve forest since *Eucalyptus salig*na an exotic species was the most dominant in the forest. Cutting of trees reduced species richness and diversity in Museve but no significant effects were observed at Mutuluni forest.

The study concludes that human activities affected tree species composition, richness and diversity for the two forest reserves but Museve forest was more disturbed than Mutuluni. Hence, there is need for proper management plans, heightened protection and monitoring of human activities in both forests with specific attention to Museve. Although grazing, foot paths and tree debarking did not reveal significant impacts in this research, it is worth considering them when designing conservation strategies for the two forests since they have been reported to affect species composition, richness and diversity directly or indirectly through creation of forest edge effects. Further research is recommended to understand the consequences of *Eucalyptus spp.*in altering tree species composition and ecological processes within Museve forest.

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REFERENCES

[1]Beentje, J. (1994). Kenya trees, shrubs and Lianas. Nairobi National Museums of Kenya, Nairobi, Kenya.

[2]FAO, (2010). Guidelines on sustainable forest management in drylands of sub-Saharan Africa; Arid Zone Forests and Forestry Working Paper No. 1, Rome, Italy.

[3]Gachathi, F. (2012). The other water towers not much is known of dryland hills and low mountains that offer a lifeline to people in ASAL. Kenya Forest Research Institute.

[4]Gonzalez, P. (2001). Desertification and a shift of forest species in the West African Sahel. *Climate Research*, 17: 217–228.

[5]Harris, H.J., Milligan M.S. and Fewless, G.A. (1983). Diversity quantification and ecological evaluation in freshwater marshes. Biological conservation vol. 27 issue 2.

[6]Hitimana, J., Kiyiapi, J.L. and Njunge, J.T. (2004). Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon Moist Lower Montane Forest, western Kenya. Forest Ecology and Management 194 (2004). 269-¬291.

[7]Hitimana, J. (2000). Structure, composition and regeneration of Mt Elgon moist lower montane forest in Kenya with particular interest in *Olea Capensis subsp welwitschii*, MPhil thesis. Moi University, Eldoret.

[8]Kacholi, D.S. (2014). Analysis of Structure and Diversity of the Kilengwe Forest in the Morogoro Region, Tanzania. International Journal of Biodiversity, Vol. 2014, ID 516840, Retrieved 23 June, 2014, from http://dx.doi.org/10.1155/2014/516840

[9]Kent, M. and Corker, P. (1992). Vegetation Description and analysis: A practical approach Chichester: John Wiley & Sons.

[10]KFS, (2012). The forester. A quarterly magazine of the Kenya forest service. January-March. Karura in Narobi: Kenya forest service.

[11]KFS, (2009). A Guide to On-Farm Eucalyptus Growing in Kenya. Nairobi, Government printer.

[11]MENR and BTC, (2002). Kitui District Forestry Master Plan. Nairobi: Government Printer.

[12]Kiruki, H., Emma, H., Zanden, E., Malek, Z. and Verburg, P. (2016). Land Cover Change and Woodland Degradation in a Charcoal Producing Semi-Arid Area in Kenya. Wiley Online Library, Retrieved 11 October, 2016, from wileyonlinelibrary.com.

[13]Kigomo, B.N. (2003). Forests and woodlands degradation in dryland Africa: A case for urgent global attention. A paper submitted to the XII world forestry congress in 2003 Quebec City Canada. Retrieved 3 December, 2015, from www.fao.org/docrep169-B3.

[14]Lou, J. (2006). *"Entropy and diversity"*. *Oikos*113(2): 363–375.

[15]Mahbud Uddin A. (2008). Underlying Causes of Deforestation and Forest Degradation in Bangladesh. University of Dhaka, Bangladesh.

[16]Marimon, B.S. and Felfili, J.M. (1997). Structure of a monodominant forest of BrosimumrubescensTaub in Nova Xavantina-MT, Brazil; Proceedings of the International Symposium on assessment and monitoring of Forests in Tropical Dry Regions with special reference to Gallery Forests Nov. 1996, *Brasilia* 215-230.

[17]Mathu, W. (2011). Forest plantations and woodlots in Kenya. Nairobi: African forest forum.

[18]Maundu, P. and Bo Tengnas, B. (2005). *Useful trees and shrubs of Kenya*. World Agroforestry Centre Eastern and Central Africa Regional Programme (ICRAF-ECA). Nairobi, Kenya.

[19]Mbuvi, M.T., Nahama, E.T. and Musyoki, J.M. (2010). "Socio-economic Report for Kavonge and Mũseve Hill-top forests". A consultant report for Kalundu and Nzeeũ Rivers Environmental Conservation Group, Kitui.

[20]Middleton, N.J. and Thomas, D. (1997). World Atlas of Desertification. UNEP, Arnold, London. UK.

[21]MEA (2005). Ecosystems and Human Well-Being: Biodiversity Synthesis. Washington, D.C.: World Resources Institute.

[22]MoA (1983). Farm Management Handbook of Kenya Vol. II – Part C Natural Conditions and Farm Management Information. East Kenya (Eastern and Coast provinces), Nairobi.

[23]Morris, R.J. (2010). Anthropogenic impacts on tropical forest biodiversity: a network structure and ecosystem functioning perspective. Retrieved May 4, 2015, from doi:10.1098/rstb.2010.0273.

[24]Mutiso, F.M, Cheboiwo, K.J., Mware, J.M., Sang, F. and Tarus, G.K. (2015). "Floristic Composition, Affinities and Plant Formations in Tropical Forests: A Case Study of Mau Forests in Kenya". International Journal of Agriculture and Forestry 5(2): 79-91.

[25]Mutiso, F.M., Hitimana, J., Kiyiapi, J.L., Sang, F.K. and Eboh E., (2013). Recovery of Kakamega Tropical Rainforest from Anthropogenic Disturbances*. Journal of Tropical Forest Science 25(4): 566–57.*

[26]Njunge J. and Mugo J. (2011). Composition and succession of the woody flora of South Nandi forest Kenya. *Research Journal of Botany,* 6: 112-121.

[27]Obiri, J.F. (2011). Invasive plant species and their disaster-effects in dry tropical forests and rangelands of Kenya and Tanzania*. Journal of Disaster Risk Studies, Vol. 3, No.2.*

[28]Ochola, W., Sanginga, P.C. and Bekalo I. (2010). Managing Natural Resources for Development in Africa: A Resource Book. Nairobi: University of Nairobi Press.

[29]Omeja, P., Obua, J. and Cunningham, B. (2004). "Regeneration, density and size class distribution of tree species used for drum making in central Uganda". *African Journal of Ecology*. 42, 129–136.

[30]Omoro, L.M. (2012). Tree species diversity, richness, and similarity between exotic and indigenous forests in the cloud forests of Eastern Arc Mountains, Taita Hills, Kenya. Academic dissertation for the Dr. Sc. (Agr. & For.) Faculty of Agriculture and Forestry of the University of Helsinki.

[31]Omoro, L. Pellikka, Rogers C. (2010). Tree species diversity, richness, and similarity between exotic and indigenous forests in the cloud forests of Eastern Arc Mountains, Taita Hills, Kenya. Journal of Forestry Research. Volume 21, Number 3, 255-264.

[32]Sovu V. (2011). Forest restoration on degraded lands in Laos. PhD Thesis No. 2011:20, Faculty of Forest Sciences, Swedish University of Agricultural Sciences, Alnarp.

[33]UNEP (2007). *Global Environment Outlook*. Environment for development. Nairobi, Kenya.