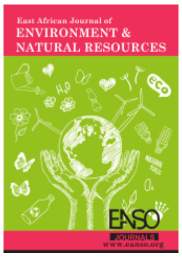

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Original Article

Effect of Disturbances on Non-tree Species Richness, Diversity, Distribution, and Abundance in Seasonally Dry Riverine of Engareolmotonyi, Arusha, Northern Highlands of Tanzania.

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Nontree Species, Richness, Distribution, Abundance, Afromontane, Seasonally Dry Riverine, Engareolmotonyi, Northern Highlands of Tanzania.

ABSTRACT

The non-tree species including shrubs, herbs, sedge, grasses, and ferns are vital for the sustainability of the forest ecosystem. The study was conducted at Engareolmotonyi seasonally dry riverine forest, in northern Tanzania to determine the non-tree species richness (S), diversity, distribution, and abundance. A total number of 20 plots measuring 20 x 20 m^2 were purposively established, within which nested plots of 1 x 1 m^2 were set to determine herbs, sedge, grasses, and ferns; whereas the 2 x 5 m^2 subplots were established to identify the woody non-trees for their botanical names, counted for their number of stems, and disturbances were recorded. Shannon index (H') of diversity was used to determine species diversity. Relative frequency (RF) was used to determine the distribution percentage and relative abundance for determining the abundance. A total of 50 non-trees species were identified. Of all those, 30 were non-woody while 20 were non-tree woody plants. Non-woody plants had higher H' and RF than woody non-trees. The non-tree woody plants had less density than non-woody plants. The most abundant species had a RD of 26.121 ± 15.30.3, while the medium had the RF of 10.290 ± 4.222, and the rest were the least abundant with an RD of ≤ 4.222. The recorded disturbances were; cutting sticks, and poles (for snaring), collection of livestock fodder plants. The relative frequency of disturbances ranged from 37.50% ± 3.13%. The most dominant disturbance was footpath (s) with a relative frequency (RF) of 37.50%), followed by cutting (21.88.14%), livestock fodder collection (12.50%), the intact plots and firewood collection (19.38%), blue monkey and baboon foot tracks (6.25), and snares had the RF

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of 3.13%. The effect of disturbances on non-trees has been noticed in Engareolmontonyi forest even though the plant diversity remains relatively high. This implies that moderate disturbance has no significant damage to plant richness, diversity, distribution and abundance. The widely distributed plants with a larger number of stems have more advantage of survival than the least distributed in terms of any damage occurring to a part of the seasonally dry riverine forest. Conclusively, the tropical vegetation can tolerate moderate or controlled activities, while excessive disturbances will always lead to a decline in richness, diversity, distribution, abundance, and even extinction of the least distributed and even the most abundant plants depending on the disturbance severity. Restoration of gaps is needed, cutting of trees and snaring should be discouraged, livestock fodder collection should be controlled.

APA CITATION

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INTRODUCTION

The nontree species including shrubs (woody plants), herbs, sedge, grasses, and ferns contribute to the species richness of the tropical forest (Gentry & Dodson, 1987). It has been pointed out that nontrees, especially shrubs are known as important tree regeneration niches (Rodriguez-Garcia *et al.,* 2011; Holeksa, 2003). The nontree species richness, diversity, distribution, and abundance have been revealed to be affected by human activities (Miller & Lugo, 2009). It has been pointed out that in the forests, the competitive interactions within the herb layer can determine the initial success of plants occupying higher strata, including the regeneration of dominant overstory tree species (Elliott *et al.*, 2014). Despite a growing awareness that the herbaceous layer serves a special role in maintaining the structure and function of forests, this stratum remains an underappreciated aspect of forest ecosystems (Gillian, 2007). The nontree species serve as part and parcel of the riverine forest ecosystem patterns, even though little is known about their spatial existence (Da Silva & Bates, 2002). The plant species abundance and distribution are being analysed on their various spatial scales. The relationship between species abundance and geographic distribution is a central issue in modern

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ecological studies, and the relationship has important implications for the understanding of community structure and for the description of biodiversity patterns (Leite & Lopes, 2001). The diversity and distribution of plants are being affected by a number of parameters (Fonge *et al.*, 2013), most of them being human agents including firewood and pole collection, charcoal, encroachment, and livestock grazing.

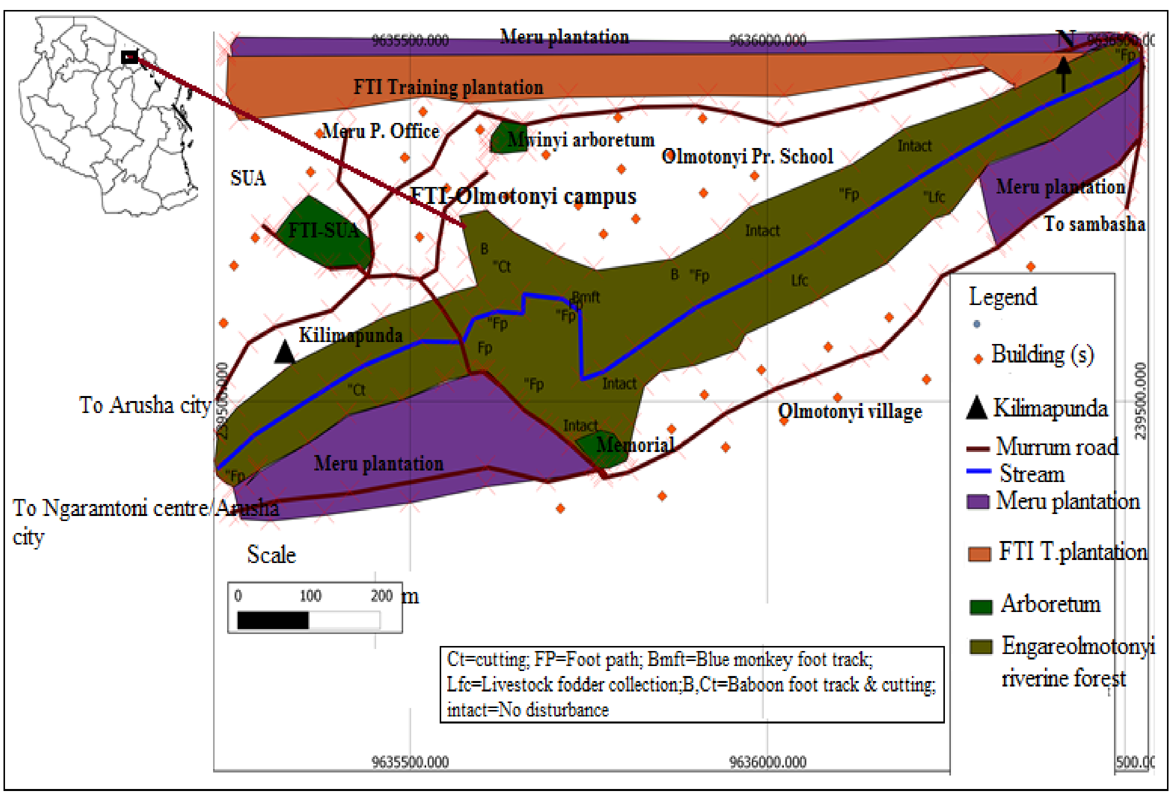
The disturbances in the ecosystem can be both natural and human-caused, of which human causes are known to be more severe. It has been pointed out that information on human disturbance in natural vegetation remains scarce as yet (up to now) to be studied thoroughly (Sebald *et al.*, 2019). Human disturbances on natural ecosystems shape forest systems by manipulating their composition, structure, and functional processes (Dale *et al.*, 2001). Indeed, the forests of Tanzania, just like in other countries are shaped by their land-use and disturbance antiquity (history) (URT, 2006; Lupala *et al.*, 2015). In Tanzania, human disturbances having the greatest effects on forests include wildfire, encroachment, livestock grazing, the introduction of invasive plants, cutting for poles, and firewood collection (Rijo *et al.*, 2013). It has been pointed out that forest disturbances influence how much carbon is stored in trees or dead wood and the wild biological diversity (Obiri, 2011; Kayombo *et al.*, 2020). This survey aimed to determine the nontree species richness, diversity, distribution and abundance of Engareolmotonyi seasonally dry riverine forest.

MATERIAL AND METHODS

Description of the Study Area

The study was conducted at the Engareolmotonyi seasonally dry riverine forest, which is about 17km northwest of Arusha city centre, and 3km north of Arusha-Nairobi Road junction at Ngaramtoni township centre. The riverine forest is bordered by the Forestry Training Institutes, the Olmotonyi campus on the west and east, the Olmotonyi village on the northeast.

Figure 1: Location of Engareolmotonyi seasonally dry riverine forest



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Vegetation Type

The vegetation of Enrageolmotonyi is a seasonally dry riverine forest (*Plate 1*) with trees like *Croton macrostachyus* Hochst. ex Delile, *Croton megalocarpus* Hutch., *Albizia gummifera* (J.F. Gmel.) C.A. Sm. and *Cussoniaholstii*Harms ex Engl. The shrubs include *Abutilon longicuspe* Hochst.*;* while the herbs and grasses include *Hypoestes aristata* (Vahl) Roem. & Schult, *Acalypha volkensii* and *Justicia flava* (Forssk.) Vahl. (herbs), *Cynodondactylon* (L.) Pers., *Panicum trichocladum* Hack. ex K. Schum and *Setaria megaphylla* (Steud.) T. Durand &Schinz (grasses).

Plate 1: Part of Seasonally dry Engareolmotonyi riverine forest

Climate

The climate temperature is chill during winter and warmer towards autumn and summer. In winter, there is much less rainfall in Arusha than in summer. This climate is considered to beCwb according to the Köppen-Geiger climate classification. The average annual temperature of Arusha is 19.2 °C (66.7 °F), with rainfall ≥ 1100 mm (43.4 inches) (URT, 2020).

Socio-economic activities of the local community

The area is surrounded by people with different activities including very few employees at the Forestry Training Institute, Olmotonyi, Meru Plantation, SUA centre, and Olmotonyi primary school, while the majority are just small-scale business dealers and agriculture crop growers through Taungya provided plots and very small plots at their homesteads. The local community hasa

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very high demand for woody fuel and livestock feeding forest resources and thus spending as much time as possible to jump into the conserved area of the natural training riverine forest of Engareolmotonyi.

Data Collection and Analysis

In this study, 20 plots of 20 x 20 m^2 (400 m^2) were purposefully established, within which the sub-plots of 1 x 1 m^2plot were set for herbs, sedge, grasses, and ferns; whereas the 2 x 5 m^2 subplots were established to identify the woody nontrees. The nontrees were identified for their botanical names and counted for their number of individuals. The observed human disturbance was recorded. Shannon index (H') of diversity will be applied to determine the nontree species diversity as per Kent and Coker (1994) & Fayiah *et al.* (2018), using H' = -∑pilnpi; where H' = Shannon wiener diversity index (index of diversity); ∑ = summation; pi $\left(\frac{\sum n}{\sum N}\right)$ = ratio of the number of stems of an individual plant species to the total number of all number of individuals of all species of the sampled area; ln=natural logarithm. The relative frequency (RF) will be calculated through ; $RF = \frac{FI}{\sum FA} \times 100\%$. Where RF = relative frequency; FI = frequency (occurrence in plots) of an individual plant species; ∑FA = overall total frequency of all plants in the sampled area. According to (Zerbo *et al.*, 2016), the frequency of species is used to examine their distribution pattern in a specific area. The nontree species abundance will be determined grounded on the relative density as reflected from the density (Fayiah *et al.*, 2018). The human disturbances occurrence (frequency) percentage (relative frequency) was determined (Sebald *et al.*, 2019).

RESULTS

Nontree plant species richness (S), Diversity, Distribution and Abundance

The nontrees include the lower growing woody plants (shrubs), while the non-woody plants include the herbs, grasses, sedges, and ferns. A total of 50 non-trees species were identified, and of those, 30 were non-woody, while from 10 families *(Table 2)*, 20 were wood nontrees (2.394) (*Table 1)*, from 18 families. Non-woody plants had the largest H' (2.260), followed by woody nontrees *(Table 1 & 2)*. Also, the largest relative frequency (RF) was determined from the non-woody plants (*Table 1& 3)*, while the nontree woody plants got less RF *(Table 1 & 2)*.

Table 1: Nontree richness(S), Shannon index of diversity (H'), and relative frequency (RF)

Variable	Richness (S)		H'		RF	
Growth form	WNT (SR)	NW	WNT(SR)	NW	WNT (SR)	NW
Value	20	30	2.394	2.26	36.082	60.309

**Key: WNT=woody non-tree (shrub); NW=non-woody.*

The most distributed nontrees woody plants had an RF of 6.701 ± 5.155, while the medium distributed had the RF of 4.639 ± 1.546, and the rest had the RF ≥ 1.545 (*Table 2*). The most distributed nontree woody plant species include *Grewia similis* K. Schum and *Abutilon longicuspe* Hochst. The medium distributed includes: *Phytolacca dodecandra* L. 'H, *Pavonia urens* Cav., *Hibiscus fuscus*Garke, *Rothecca myricoides* (Hochst.) Steane & Mabb.,and *Hoslundia opposite* Vahl. The most abundant species had an RD of 26.121 ± 15.30.3, while the medium dominant had the RF of 10.290 ± 4.222, and the rest were the least abundant with an RD of ≤ 4.222 *(Table 2)*. In this study, the following nontree woody plants were the most abundant grounded on the calculated RD; *Abutilon longicuspe* Hochst and *Grewia similis* K.Schum. The moderately abundant include: *Phytolacca dodecandra* Cav., *Pavonia urens*L.'H., and *Lippia javanica* (Burm.f.) Spreng. The nontree woody plant families with the largest number of species were; Malvaceae, Fabaceae, and Lamiaceae *(Table 2)*.

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Table 2: Shrub species richness (S), Shannon index of diversity (H'), distribution, relative density (RD)

S/N	Family name	Botanical name	Author	Ind.	F	RF	D (Ha)	RD	H'
1	Asteraceae	1. *Psiadia punctulata*	(DC) Vatke	2	1	0.515	2.5	0.528	0.028
		2. *Senecio hadiensis*	Forssk	2	1	0.515	2.5	0.528	0.028
2	Capparaceae	3. *Maerua angolensis*	DC	2	1	0.515	2.5	0.528	0.028
		4. *Maerua triphylla*	A. Rich	32	2	1.031	40	8.443	0.209
3	Euphorbiaceae	5. *Clutia abyssinica*	Jaub	5	1	0.515	6.25	1.319	0.057
4	Fabaceae	6. *Caesalpinia decapetala*	(Roth) Alston	16	2	1.031	20	4.222	0.134
		7. *Senna semptemtrionalis*	(Viv) H.S. Irwin & Bernby.	2	1	0.515	2.5	0.528	0.028
		8. *Vernonia lasiopus*	H. Hoffm	4	1	0.515	5	1.055	0.048
5	Lamiaceae	9. *Hoslundia opposita*	Vahl.	23	3	1.546	28.75	6.069	0.17
		10. *Lippia javanica*	(Burm.f.) Spreng	16	2	1.031	20	4.222	0.134
		11. *Rothecca myricoides*	(Hochst.) Steane & Mabb.	29	4	2.062	36.25	7.652	0.197
6	Malvaceae	12. *Abutilon longicuspe*	Hochst.	99	13	6.701	123.75	26.121	0.351
		13. *Hibiscus fuscus*	Garke	13	5	2.577	16.25	3.43	0.116
		14. *Hibiscus lundwigii*	L	5	2	1.031	6.25	1.319	0.057
		15. *Pavonia urens*	Cav.	20	6	3.093	25	5.277	0.155
7	Phytolacaceae	16. *Phytolacca dodecandra*	L.'He	39	9	4.639	48.75	10.29	0.234
8	Rhamnaceae	17. *Helinus mystacinus*	(Ait.) E. Mey. ex Steud	1	1	0.515	1.25	0.264	0.016
9	Rubiaceae	18. *Chassalia curviflora*	(Wall)Twaites	3	1	0.515	3.75	0.792	0.038
		19. *Pavetta abyssinica*	Fresen	8	4	2.062	10	2.111	0.081
10	Tiliaceae	20. *Grewia similis*	K. Schum.	58	10	5.155	72.5	15.303	0.287
		Total		**379**	**70**	**36.082**	**473.75**	**100**	**2.394**

The most distributed non-woody plants had a relative frequency (RF) of 8.247 ± 5.670, while the moderately distributed had an RF of 4.124 ± 2.062, and the rest were the least distributed with the Rf of ≥ 2.061 (*Table 3)*. The identified most distributed non-woody plants include *Achyranthes aspera* L *Hypoestes aristata* Soland. ex Roem & Schult, and *Acalypha volkensii* Pax. The moderately distributed include; *Justicia flava* (Forssk.) Vahl., *Thunbergia alata* Bojer ex Sims, *Tragia brevipes* Pax, *Cyathula cylindrica* Moq., *Asparagu*s *setaceus* (Kunth.) Jessop.,*Lagenaria abyssinica* (Hook.f.) C.Jeffrey, *Neonotonia wightii* (Arn.) J.A. Lackey, *Setaria megaphylla* (Steud.) Dur. &Schinz (*Table 3).*

The most abundant non-woody plant species had a relative density (RD) ranging from 24.3902 ± 6.6056, while the medium dominant had a density of ≤ 6.6055 ± 1.21951, and the least dominant hadthe RD of ≤ 1.21950. The identified most abundant nonwood\y plants embrace the; *Hypoestes aristata* Soland. ex Roem & Schult, *Achyranthes aspera* L., *Justicia flava* (Forrsk) Vahl., and *Acalypha volkensii* Pax

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Table 3: Non-woody plant species richness (S), relative frequency (RF), Shannon index of diversity (H'), density (D) and relative density (RD)

S/N	Family	Botanical name	TTIN	Frequency	RF	H'	D	RD
1	Acanthaceae	1. *Hypoestes aristate* Soland. ex Roem & Schult	240	13	6.701	0.344	300	24.3902
		2. *Justicia flava* (Forssk)Vahl.	88	8	4.124	0.216	110	8.94309
		3. *Thunbergia alata* (Forssk)Vahl.	1	6	3.093	0.007	1.25	0.10163
2	Amaranthaceae	4. *Achyranthes aspera* L.	213	16	8.247	0.331	266.25	21.6463
		5. *Cyathula cylindrica*Moq.	19	4	2.062	0.076	23.75	1.93089
3	Apocynaceae	6. *Perilploca linearifolia* Quart. -Dill. A.Rich	3	1	0.515	0.018	3.75	0.30488
		7. *Secamone punctulate* Decne	1	1	0.515	0.007	1.25	0.10163
4	Asparagaceae	8. *Asparagus setaceus* (Kunth.) Jessop.	8	4	2.062	0.039	10	0.81301
5	Aspleniaceae	9. *Pellaea viridis* (Forssk.) Plantl	13	3	1.546	0.057	16.25	1.32114
6	Asteraceae	10. *Ageratum conyzoides* L.	3	1	0.515	0.018	3.75	0.30488
		11. *Crassocephallum crepidioides* (Benth.) S. Moore	1	1	0.515	0.007	1.25	0.10163
		12. *Solanecio angulatus* (Vahl.) C. Jeffrey	5	1	0.515	0.027	6.25	0.50813
		13. *Solanecio syringifolius* O. Hoffm	2	1	0.515	0.013	2.5	0.20325
		14. *Tagetes minuta* L.	2	1	0.515	0.013	2.5	0.20325
		15. *Vernonia galamensis* (Cass.) Less	3	2	1.031	0.018	3.75	0.30488
7	Commelinaceae	16. *Commelina benghalensis* L.	12	2	1.031	0.054	15	1.21951
8	Convolvulaceae	17. *Cuscuta kilimanjari* Oliv.	5	2	1.031	0.027	6.25	0.50813
		18. *Ipomoea wightii* (Wall.) Choisy	23	3	1.546	0.088	28.75	2.3374
9	Cucurbitaceae	19. *Lagenaria abyssinica* (Hook.f.) C. Jeffrey	8	5	2.577	0.039	10	0.81301
10	Euphorbiaceae	20. *Acalypha volkensii* Pax	65	11	5.67	0.179	81.25	6.60569
		21. *Tragia brevipes* Pax	11	6	3.093	0.05	13.75	1.11789
11	Fabaceae	22. *Crotalaria ciliaris* Aiton	2	1	0.515	0.013	2.5	0.20325
		23. *Desmodium repondum* (Vahl.) DC.	5	1	0.515	0.027	6.25	0.50813
		24. *Neonotonia wightii* (Wight &Arn.) J. A. Lackey	14	4	2.062	0.061	17.5	1.42276
12	Lamiaceae	25. *Leucas densiflora* Vatke	1	1	0.515	0.007	1.25	0.10163
13	Malvaceae	26. *Abutilon hirtum* (L.) Sweet	6	2	1.031	0.031	7.5	0.60976
14	Poaceae	27. *Cynodon dactylon* (L.) Pers	195	4	2.062	0.321	243.75	19.8171
		28. *Setaria megaphylla* (Steud.) Dur. & Schinz	7	2	1.031	0.035	8.75	0.71138
15	Solanaceae	29. *Lycopersicon esculantum* Miller	1	1	0.515	0.007	1.25	0.10163
		30. *Solanum incanum* L.	13	4	2.062	0.057	16.25	1.32114
16	Tiliaceae	31. *Triumfetta rhomboidei* Jacq.	7	2	1.031	0.035	8.75	0.71138

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S/N	Family	Botanical name	TTIN	Frequency	RF	H'	D	RD
17	Urticaceae	32. *Girardiana diversifolia* (Link.) Friis	3	2	1.031	0.018	3.75	0.30488
18	Vitaceae	33. *Cyphostemma adenocaule* (Steud. Ex A. Rich) Desc.	4	1	0.515	0.022	5	0.4065
		Total	**984**	**117**	**60.309**	**2.26**	**1230**	**100**

Disturbances affecting the nontree species richness, distribution, and abundance

The disturbances were both human and natural caused. Human disturbances or activities are among agents affecting the nontree species richness, diversity, distribution and abundance. This study identified the following human disturbances at Engareolmotonyi seasonally dry riverine forest; footpaths affected the undergrowth's especially the herbs, seedlings, and grasses; cutting poles and very small trees (*Plate 2B); Papio nubis* (Olive baboon) and *Cercopithecus mitis* (Blue monkeys foot tracks) (*Plate 2C);* a collection of livestock fodder plants involved the removal of herbs, grasses together with shrubs. The collected fodder plants were *Cynodondactylon* (L.) Pers, and *Setaria megaphylla* (Steud.) Dur. &Schinz. The other disturbances were tree cutting for poles (*Clausena anisata* (Wild.) Hook), firewood (*Croton macrostachyus* Hochst. Ex Delile) and cutting poles and snaring sticks (*Plate 2A)* (*Erythrococcafischeri* Pax a process that also affects the non-trees as the trees fell on them. The natural disturbances were from wild mammals including *Papio anubis* (Oliv baboons.

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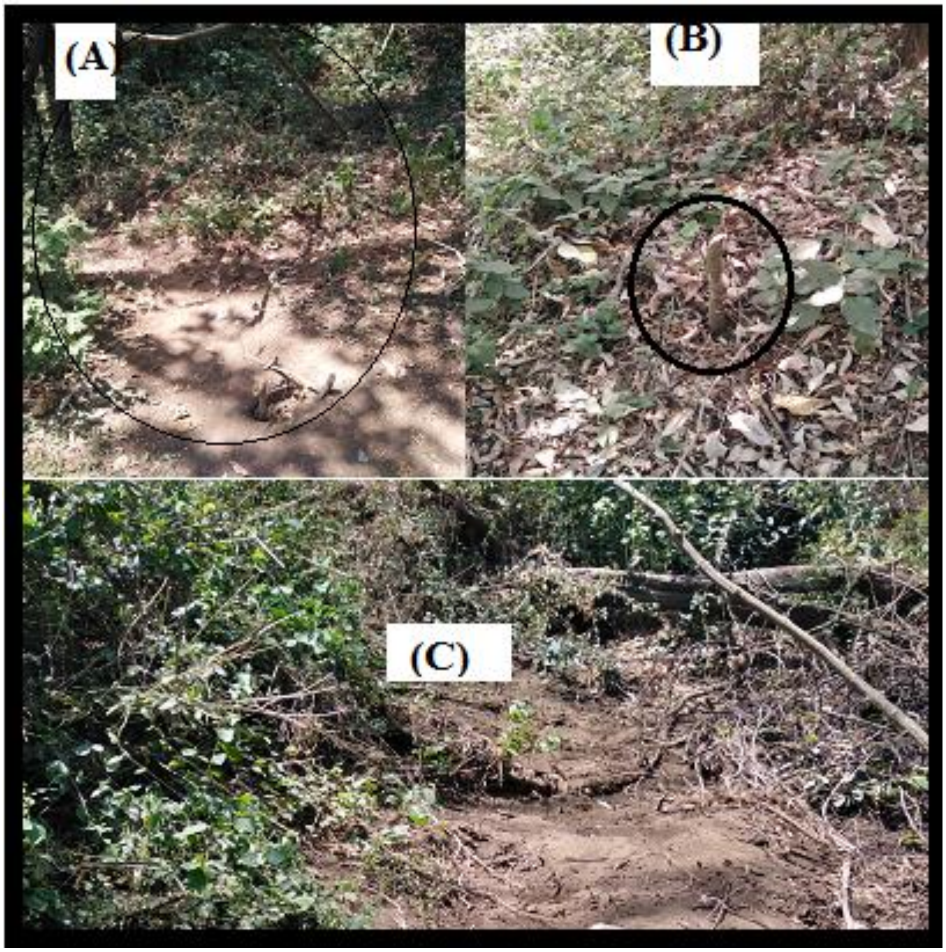
Plate 2: Snaring (A), Cutting of poles & small trees (B) & baboons foot tracks (C)



The relative frequency of disturbances ranged from 37.50% ± 3.13%. These study findings revealed the most dominant disturbance as a footpath (s) with a relative frequency (RF) of 37.50%), followed by cutting (21.88.14%), livestock fodder collection (12.50%), the intact plots and firewood collection (19.38%), blue monkey and baboon foot tracks (6.25), and snares had an RF of 3.13% (*Table 4).*

Table 4: Disturbance affecting nontree species richness, distribution and abundance

Disturbance	Frequency (F)	Relative frequency (RF)
Foot path (s)	12	37.50
Cutting	7	21.88
Livestock fodder collection	4	12.50
Intact	3	9.38
Firewood collection	3	9.38
Blue monkey & baboon foot path(s)	2	6.25
Snare(s)	1	3.13
Total	**32**	**100**

DISCUSSION

The nontree richness woody plants (shrubs) species richness (S) of 20 with an H’ of 2.394 and the S of 30 for the non-woody plants (herbs, grasses, sedge, and ferns) with the H’ of 2.260 and an overall “S” of 50 and an over average of 2.327 as per Kent and

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Coker (1992) & Mligo (2018) Quoted Kent and Coker (1992), reveals high plant diversity, like the H' for high diversity ranges from 3.5 ± 1.5 and exceptionally exceeding 4.5 a scale of 5 ± 0. The high S and H' entails minimum disturbances (Whitworth *et al.,* 2016). Moderate human use of forest ecosystems does not significantly affect the plant diversity, indicating that tropical tree diversity is compatible with human exploitation as long as the vegetation covers are being maintained by making sure that there is sustainable use of forest margins (Gradstein *et al.,* 2007). On the other hand, excessive disturbance may lead to the locally extinction of plant species. The plant species with the largest frequency and relative frequency is meant to be the most distributed within the study area (Santamaria, 2002; Burnham & Santanna, 2015), and hence ensuring longer survival against disturbances, unlike the plant which is very limited in distribution. The number of individuals is used to determine the density of biological species a result that may end up revealing the abundance (Maszura *et al.,* 2018), in a sense that more stems of any particular plant or organism mean more quantity of such plant in a given spatial area.

It has been reported that a plant species with the highest density fits for being judged as the most dominant, while the one with the least density and relative density (RD) is meant to be the least abundant (Harcourt & Parks, 2005). The highest relative frequency (RF) of the footpath(s) (41.38%) implies that local people get into the riverine forest regularly when seeking either firewood, poles, and livestock fodder plants that are being harvested haphazardly and get out of the forest (Wanleys Consultancy Service, 2013). Tree cutting for poles and rarely for trees is done because of the high pressure of an everlasting need for livestock kraals, firewood and snares, and thus affecting the ecosystem as trees are part and parcel of the forest functioning ecosystem (Dunker *et al.,* 2012). The removal of trees disturbs the habitat for nontrees (woody and herbaceous plants) which need shade or shade tolerance but are affected by excessive light (Pamerleau-Couture *et al.,* 2015). The 9.38% of the intact plots meant that most of the riverine forest had been impacted (90.62%) (Table 4), even though the disturbances were rather so minimal in most sample plots, they were recorded, and thus still leaving the area with high plant diversity. It has been reported that severe or excessive disturbances in tropical forests damage plant species of which some of them may become extinct in a particular locality. Alroy (2017), who conducted a study in the tropical forests of the world, found that all the disturbed habitats put together included 41% fewer species than the undisturbed forests.

CONCLUSION

The consequences of disturbances being natural or human-influenced factors *(Table 4)* have an effect on the biodiversity richness, diversity, distribution, and abundance in the natural forests. The removal of plants for firewood, livestock fodder, and wild animals snaring sticks reduces the richness (S) diversity and also limits the distribution extension and the quantity (density). Trampling by either human beings or wild animals form paths and or footpaths on which lower plants are being damaged. Snaring requires cleaning the snaring site (*Plate 2C),* a situation that leads to damage of both nontree plants and the small tree regeneration including seedlings and saplings. The most distributed plants *(Table 3)* have a chance for survival, while the limited (*Table 3)* ones in distribution are prone to damage in case disturbance occurs in such locations. The plants with more stems have a chance of being distributed in a large area and hence minor damage on a small area may have fallen under less or no significant damage on such taxon. Engareolmotonyi seasonally dry riverine forest is a potential area offering various ecosystem services including; regulation of temperature, protection of water services, habitat for wildlife, windbreak, dead firewood, home for wildlife (mammals, reptiles, and insects), training facility (ecology, forest conservation, environmental conservation, ecotourism, forest survey, forest inventory). Further study is needed to explore the ecotourism attractions and establish ecotourism venture as a non-wood income-generating project, education to local people on the effect of collecting grasses herbs together with tree seedlings, participatory management of the site, and restoration of the degraded riverine forest areas (forest gaps).

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