

Research Article

Plant Species Composition and Structure in Areas Impacted with Invasive Alien Plants (IAS) at Eastern Ridge Top of Duluti Lake Catchment Forest Reserve, Northern Tanzania

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Abstract

The eastern ridge of Duluti Lake Catchment Forest (DLCF) harbors high plant species diversity within the bush land and woodland. Concentric plots were established to analyze the existing plant species of the area. The recorded plant species were indicated for whether indigenous, alien, alien and invasive. Shannon Wiener Diversity index was applied to calculate diversity index of shrubs and trees. Trees and shrub densities were calculated. Herbaceous plants, shrubs, and trees distribution were evaluated. During this study, a total of 113 herbaceous plants, shrubs, and trees were recorded. The calculated H' for shrubs and trees ranged from ≤ 3.5 - ≥ 1.5 an implication of high diversity. The densest plant species was an alien invasive plant, *Lantana camara* L. indicating that the area is dominated by alien invasive plants. The eastern ridge of Duluti Lake Catchment Forest accommodates high plant species diversity that requires management. Further study is needed, control alien invasive plants, replace the existing alien plants with indigenous plants.

Keywords

Alien Plants, Duluti Lake Catchment Forest Reserve, Index of Diversity, Invasive Plant

1. Introduction

Catchment forest reserves are meant for conservation of native plant species for the sake of sustainable supply of water [32]. Forest reserves focus on environmental objectives which are to conserve the ecosystems, and to protect water catchment area so as to help control droughts floods and prevent soil erosion [5, 27]. Analyses of plant species composition reveal the spread of alien invasive plant species through specific indicators and patterns, including the decline of native species diversity, altered abundance and dominance patterns, and the correlation with environmental and anthropogenic factors [4,

11, 51]. Alien plants are exotic or non-native, also called non-indigenous or foreign plant species that have been introduced by people either intentionally or unintentionally outside of their natural range and outside of their natural dispersal potential (20). While alien invasive plant species are both alien and destructive to the new environment in which they grow, as such invasive plants can have negative impacts on biodiversity and or livelihoods [36, 47]. Some alien plants may just be exotic but not invasive while others can be both alien and invasive [45].

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Lantana camara L., a native plant from tropical America, is considered one of the most harmful invasive species worldwide [15]. A number of scientific studies suggest that many invasive plants do not conserve their niches [25]. Invasive alien plants are a major cause of global biodiversity loss, fundamentally altering forest ecosystems and posing significant ecological and economic threats [13, 36]. Invasive alien plants displace native flora and fauna by outcompeting them for resources, changing habitats, and disrupting the intricate balance of natural environments [2]. Natural forest invasion is a global issue caused by the spread of non-native organisms like insects, pathogens, and plants [23, 28]. The species known to be invaders disrupt ecosystems by outcompeting native species, causing ecological damage, and leading to significant economic losses in forestry, agriculture, and infrastructure [39]. African countries, with attractive indigenous plant composition embedded in grasslands, forests, woodlands, and other habitats, faces severe invasion of exotic plant species, while most of them are not easily recognized by the conservators or forest reserves managers [6]. When alien invasive are recognized, it does not focus most on lower plants than the trees such as herbaceous plants, and shrubs, and sometimes it is even difficulty because of inadequate number of committed botanists [5].

The continuing flourishing and spread of invasive alien plant species in East Africa has been known as a serious problem which needs to be addressed [48]. Tanzania's diverse natural forests and protected areas face significant threats from high invasion by various alien plant species [26]. Duluti Lake Catchment Forest Reserve (DLCFR) which is being visited by tourists nearly every day is rich in plant species diversity, with each of them being distributed at different levels and varying relative abundance [43]. Plant species richness reveals the total number of species and their diversification in a given area [42]. Plant species density reveals the quantity of individuals per unit occupied area [16]. The distribution of plant species at a given area provide a broad information on their known localities and boundaries of their presence [12].

1.1. Problem Statement and Justification

The global importance of tropical forest reflects their enormous and celebrated biological diversity which includes a high proportion of endemic species, and their importance to a planet experiencing the greenhouse effect; as a vast sinks for carbon, and key components in global water cycle, tropical forests delivery ecosystem services that benefit the entire planet [3]. Despite this wealth of plant life, relatively little is known about flora of many areas and there are far too few trained botanists to recognize the plant varieties [17]. The world countries natural vegetation composition facing severe invasion of alien plant species, even though little is known on their existence and spreading level [29, 33]. African countries, collectively suffer from invasive alien plants in both forest

reserves and national parks, a condition that ruins the marketability of nature [19]. The management of invasive alien plant species in many regions including East Africa has been hindered by a number of factors, among them being inadequate information [48]. Tanzania, with attractive forest reserves suffers from alien plant species invasion, however, inadequate information remains a challenge on which species exist, and their locations within each particular forest reserve [14].

Duluti Catchment Forest Reserve is a famous tourism center situated near Arusha city whereby a number of foreigners and citizens tour regularly for relaxation. Few studies had been conducted on flora and fauna of the area, however, inadequately has been explored addressing the invasive alien plant taxa. This study intended to explore the plant species richness and diversity, density, percentage cover of herbaceous plants within the *Lantana camara* L invaded patches of the eastern side ridge of Duluti Catchment Forest Reserve in northern Tanzania. This information with expose the existing invasive alien plants thus stimulating their spreading control by the authorities.

1.2. Objectives

This study dealt with assessment of plant species composition and structure at areas invaded by alien invasive plants (IAS) on eastern ridge top of Duluti Lake Catchment Forest Reserve, and the specific objectives were (i) to analyze the plant species richness and diversity (ii) to estimate the density of woody plant species (iii) to investigate the plant species distribution at eastern ridge of Duluti Catchment Forest Reserve?

1.3. Research Questions

The accompanied research questions where (i) what is the plant species richness and diversity? (ii) What is the density of woody plant species?, and (iii) what is the plant species distribution at eastern ridge of Duluti Catchment Forest Reserve?

2. Methodology

2.1. Location of Study Area

The reserve is located in the Northern tourism circuit in Arusha Region and it covers an area of 86.24Ha including a crater lake of 60Ha, which is the determinant of the surrounding moist forest. Lake Duluti Forest is accessible by road about 14km from Arusha City center and 1.3km from Tengeru town [43]. However, the study was conducted at the eastern ridge of Duluti Lake Catchment Forest, starting from the TFS Office to the communication tower which was about 200 m towards south, and the *Lantana camara* patch “B” was further south of the *Lantana camara* L. patch “A”. The total

size of the two *L. camara* patches was 1.744 Ha (≈ 1.8 Ha). The size of the *Lantana camara* “A” patch (Figure 1) was 0.47 ha (≈ 0.5 ha).

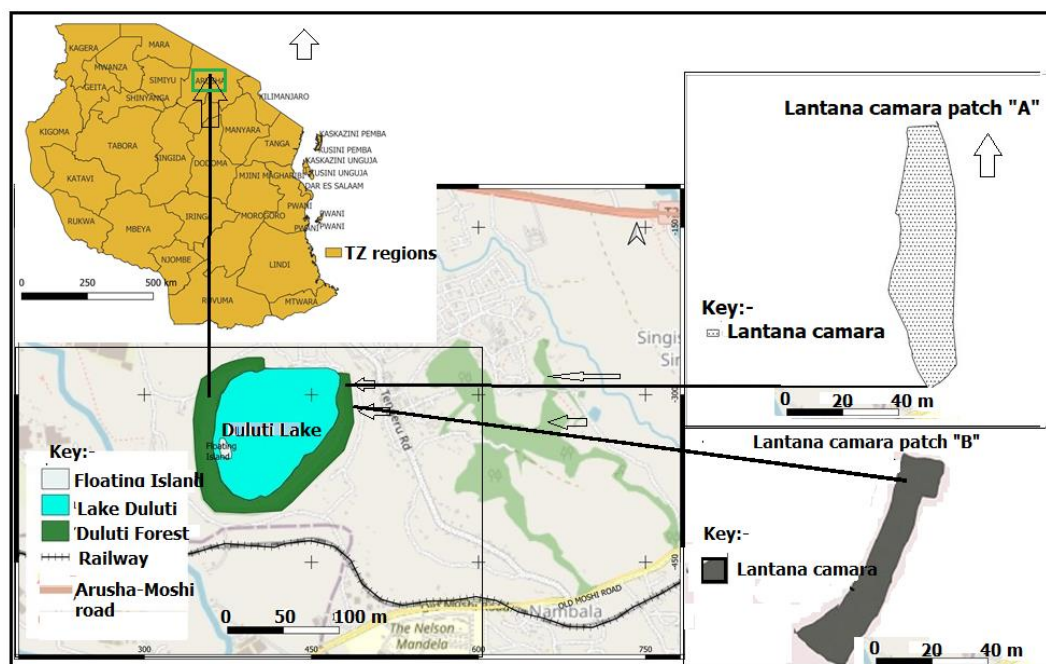


Figure 1. Sampling Patch “A” and “B” [Source: Field Data, 2025].

The size of *Lantana camara* patch “B” was measured to be 1.274 Ha (≈ 1.3 Ha) (Figure 2).

2.2. Data Collection Methods

A total of 26 rectangular plots of 10 m x 10 m (100 m²) were established at *Lantana camara* L. site “A” (Figure 1) and “B” (Figure 2). All tree species encountered in the 100 m² sample plots were recorded and counted for their number of individuals. Concentric rectangular plots of 2 m x 5 m were established to evaluate the shrubs/woody climbers, which were recorded for botanical names and counted for their individuals. Also, 1 m x 1m quadrants were established to examine the tree seedlings that were recorded for their botanical names and counted for their number of individuals: in the same quadrat (1 m²) all tree seedlings were recorded and counted for their number of individuals.

2.3. Data Analysis

2.3.1. Plant Richness and Diversity Index

The plant richness was observed from the overall list of plant species of such category as recorded from the sample plots. The diversity was calculated through Shannon wiener index of diversity (H') [24], $H' = -\sum p_i \times \ln p_i$; where, H' = Shannon wiener index of diversity; ln = natural logarithm; p_i = proportion of individuals of a single plant species (n) to an overall count of all individuals of all recorded plant species

(N).

2.3.2. Relative Density per Hectare (RD/ha)

The RD/ha was calculated grounded on the densities of every recorded plant species, through;

$RD/ha = \frac{\sum nD}{\sum ND} \times 100$ [46]; Where; RD/ha = relative density per hectare; $\sum nD$ = density of a single plant species; $\sum ND$ = density of all plant species of such category recorded from sample plots. It has been stated that relative density is a measure of the numerical abundance or numerical strength of a species in a community [47].

2.3.3. Distribution of Plants

This was obtained from the recorded frequency (F) of every recorded plant species. Plant species relative frequency is important because it helps measure biodiversity, indicates species distribution and dominance, and provides a tool for ecological assessment and restoration, it reveals how widespread a species is within a given area, which is crucial for understanding community structure, predicting population stability, and identifying at-risk species [52].

Therefore the distribution was judged grounded on the calculated relative frequency (RF), through;

$RF! = \frac{nF!}{NF!} \times 100$ Where, RF! = relative frequency; nF! = frequency of a single plant species; NF! = an overall total frequency of all recorded plant species from sample plots.

2.3.4. Importance Value Index (IVI)

This was calculated by adding up relative density (RD/ha) and relative frequency (RF), through; $IVI = RD/ha + RF$. The importance value index (IVI) measures how dominant a species is in a given forest area [40, 41].

2.4. Presentation of Findings

The findings have been presented in figures, plates, and tabular forms accompanied with describing statements.

3. Results

Vegetation types (Habitats) of the eastern ridge top of Duluti Lake Catchment Forest.

3.1. Bush Land/Shrub Land

This habitat (Figure 2) was massively covered by *Lantana camara* L., with very scattered trees of *Osyris lanceolata*, *Vangueria madagascariensis*.



Figure 2. Bush Land with Scattered Trees.

3.2. Woodland

Out of the 15 sample plots, only one plot was recorded to be a woodland [Figure 2] dominated with *Croton megalocarpus* Hutch. *Osyris lanceolata*, and *Vangueria madagascariensis* J. F. Gmel.



Figure 3. Woodland.

3.3. Plant Species Richness, Diversity Index, and Distribution

3.3.1. Plant Species Richness and Diversity

A total of 113 plant species were recorded at eastern ridge of Duluti Lake Catchment Forest Reserve, of which 54 (47.8%) were herbaceous, 33 were trees (29.2%), and 26 were shrubs (23%). The calculated index of diversity was 2.0 for shrubs/woody climbers and 2.8 for trees (Tables 1-6).

Table 1. Total Plant Species Per Growth Form.

Growth form	Total species	Percentage (%)	H'
Herb	54	47.8	-
Shrub	26	23.0	2.0
Tree	33	29.2	2.8
Total	113	100	

Tree species, density, and distribution

A total of 33 tree species were recorded with the calculated Shannon wiener index of diversity of 2.77 (2.8). The highest relative density (RD/ha) was recorded in *Osyris lanceolata*, *Croton megalocarpus*, and *Vangueria madagascariensis* with

the $RD/ha = \leq 24.07 - \geq 11.57$ and the IVI of $\leq 34.92 - \geq 21.21$. The most distributed tree species capture the relative frequency (RF) of $\leq 10.84 - 7.23$, and those were *Combretum molle*, *Osyris lanceolata*, *Croton megalocarpus*, and *Vangueria madagascariensis*. The rest trees got the RF of

<7.23 (Table 2).

Table 2. Tree Species Diversity Index, and Distribution.

S/N	Botanical name	Author	Family	IN	A	IS	TTC	F	H'	D/ha	RF	RD/ha	IVI
1	<i>Albizia glaberrima</i>	(Schum.& Thonn) Benth	Fabaceae	1	0	0	2	1	0.04	7.7	1.20	0.93	2.13
2	<i>Albizia petersiana</i>	(Bolle) Oliv.	Fabaceae	1	0	0	7	1	0.11	26.9	1.20	3.24	4.45
3	<i>Allophylus africanus</i>	P. Beauv.	Sapindaceae	1	0	0	5	3	0.09	19.2	3.61	2.31	5.93
4	<i>Cedrella odorata</i>	L.	Meliaceae	0	1	1	2	2	0.04	7.7	2.41	0.93	3.34
5	<i>Clausena anista</i>	(Willd.) Hook. f. ex Benth.	Rutaceae	1	0	0	1	1	0.02	3.8	1.20	0.46	1.67
6	<i>Combretum molle</i>	R. Br. ex G. Don	Combretaceae	1	0	0	9	6	0.13	34.6	7.23	4.17	11.40
7	<i>Croton macrostachyus</i>	Hochst. ex Delile	Euphorbiaceae	1	0	0	6	2	0.10	23.1	2.41	2.78	5.19
8	<i>Croton megalocarpus</i>	Hutch.	Euphorbiaceae	1	0	0	27	9	0.26	103.8	10.84	12.50	23.34
9	<i>Diospyros abyssinica</i>	(Hiern) F. White	Ebenaceae	1	0	0	2	1	0.04	7.7	1.20	0.93	2.13
10	<i>Dombeya rotundifolia</i>	(Hochst.) Planch	Malvaceae	1	0	0	2	1	0.04	7.7	1.20	0.93	2.13
11	<i>Ekebergia capensis</i>	Sparrm	Meliaceae	1	0	0	1	5	0.02	3.8	6.02	0.46	6.49
12	<i>Erythrina abyssinica</i>	Lam. ex DC.	Fabaceae	1	0	0	1	1	0.02	3.8	1.20	0.46	1.67
13	<i>Euclea divinorum</i>	Hiern.	Ebenaceae	1	0	0	2	1	0.04	7.7	1.20	0.93	2.13
14	<i>Ficus exasperata</i>	Vahl.	Moraceae	1	0	0	1	1	0.02	3.8	1.20	0.46	1.67
15	<i>Ficus lutea</i>	Vahl.	Moraceae	1	0	0	1	1	0.02	3.8	1.20	0.46	1.67
16	<i>Flueggea virosa</i>	(Roxb. ex Willd.) Royle	Phyllanthaceae	1	0	0	7	2	0.11	26.9	2.41	3.24	5.65
17	<i>Grevillae robusta</i>	A. Cunn. ex R. Br	Proteaceae	0	1	0	11	5	0.15	42.3	6.02	5.09	11.12
18	<i>Leucaena leucocephala</i>	(Lam.) de Wit	Fabaceae	0	1	1	2	1	0.04	7.7	1.20	0.93	2.13
19	<i>Markhamia lutea</i>	(Benth.) K. Schum.	Bignoniaceae	1	0	0	1	1	0.02	3.8	1.20	0.46	1.67
20	<i>Montanoa hibiscifolia</i>	Benth.	Asteraceae	0	1	1	2	1	0.04	7.7	1.20	0.93	2.13
21	<i>Neubotonia macrocalyx</i>	Pax	Euphorbiaceae	1	0	0	1	1	0.02	3.8	1.20	0.46	1.67
22	<i>Oncoba spinosa</i>	Forssk.	Flacourtiaceae	1	0	0	2	1	0.04	7.7	1.20	0.93	2.13
23	<i>Opuntia ficus-indica</i>	(L.) Mill.	Cactaceae	0	1	1	1	1	0.02	3.8	1.20	0.46	1.67

S/N	Botanical name	Author	Family	IN	A	IS	TTC	F	H'	D/ha	RF	RD/ha	IVI
24	<i>Osyris lanceolata</i>	(Hochst.) Steud.	Santalaceae	1	0	0	25	8	0.25	96.2	9.64	11.57	21.21
25	<i>Ozoroa insignis</i>	Delile	Anacardiaceae	1	0	0	2	1	0.04	7.7	1.20	0.93	2.13
26	<i>Phyllonoptera eriocalyx</i>	(Harms) Schrire	Fabaceae	1	0	0	1	1	0.02	3.8	1.20	0.46	1.67
27	<i>Searsia natalensis</i>	(Bernh. ex C. Krauss) F. A. Barkley	Anacardiaceae	1	0	0	4	3	0.07	15.4	3.61	1.85	5.47
28	<i>Searsia vulgaris</i>	Meikle	Anacardiaceae	1	0	0	4	1	0.07	15.4	1.20	1.85	3.06
29	<i>Senna siamea</i>	(Lam.) H. S. Irwin & Barneby	Fabaceae	1	0	0	10	4	0.14	38.5	4.82	4.63	9.45
30	<i>Senna spectabilis</i>	(DC.) H. S. Irwin & Barneby	Fabaceae	1	0	0	14	3	0.18	53.8	3.61	6.48	10.10
31	<i>Turraea robusta</i>	Gurke	Meliaceae	1	0	0	6	3	0.10	23.1	3.61	2.78	6.39
32	<i>Vangueria madagascariensis</i>	J. F. Gmelin	Rubiaceae	1	0	0	52	9	0.34	200.0	10.84	24.07	34.92
33	<i>Vernonia amygdalina</i>	Del.	Asteraceae	1	0	0	2	1	0.04	7.7	1.20	0.93	2.13
Total				28	5	4	216	83	2.77	830.8	100	100	200
Percentage (%)				85	17	13							

3.3.2. Trees and Their Regeneration Diversity Indices

During this study, a total of 26 tree species regeneration were recorded, and of those, 23 were indigenous (88%), three (3) were alien (12%), while two of the alien species were also, invasive. The most dense tree species regeneration got the RD/ha of ≤ 15.6 - ≥ 4.7 , with the IVI of ≤ 20 - ≥ 7.8 . The recorded tree species regeneration under this category were;

Clausena anisata, *Euclea divinorum*, *Osyris lanceolata*, *Searsia natalensis*, *Senna siamea*, *Senna spectabilis*, *Turraea robusta*, *Vepris simplicifolia*. On the other hand, the most distributed tree species regeneration got the relative frequency (RF) of ≤ 10.8 - ≥ 7.7 , and the recorded species under this category were *Clausena anisata*, *Osyris lanceolata*, *Turraea robusta*, *Vepris simplicifolia*, while the rest got the RF of < 7.7 (Table 3).

The diversity indices for both tree regeneration were 2.88 and 2.76 for mature trees (Table 3).

Table 3. Diversity Indices of Tree Regeneration and Mature Trees.

S/N	Botanical name	Author	Family	TRGTTC	TTTC	H'TRG	H'T
1	<i>Albizia glaberrima</i>	(Schumach. & Thonn.) Benth.	Fabaceae	0	2	0.00	0.04
2	<i>Albizia petersiana</i>	(Bolle) Oliv.	Fabaceae	3	7	0.06	0.11
3	<i>Albizia schimperiana</i>	Oliv.	Fabaceae	3	0	0.06	0.00
4	<i>Allophylus africanus</i>	P. Beauv.	Sapindaceae	2	5	0.04	0.09
5	<i>Cedrella odorata</i>	L.	Meliaceae	0	2	0.00	0.04

S/N	Botanical name	Author	Family	TRGTTTC	TTTC	H'TRG	H'T
6	<i>Celtis africana</i>	Burm. f.	Cannabaceae	1	0	0.03	0.00
7	<i>Clausena anisata</i>	(Willd.) Hook. f. ex Benth.	Rutaceae	18	1	0.21	0.02
8	<i>Combretum molle</i>	R. Br. ex G. Don	Combretaceae	6	9	0.10	0.13
9	<i>Commiphora eminii</i>	Engl.	Burseraceae	2	0	0.04	0.00
10	<i>Croton macrostachyus</i>	Hochst. ex Delile	Euphorbiaceae	0	6	0.00	0.10
11	<i>Croton megalocarpus</i>	Hutch.	Euphorbiaceae	2	27	0.04	0.26
12	<i>Diospyros abyssinica</i>	(Hiern) F. White	Ebenaceae	0	2	0.00	0.04
13	<i>Dombeya rotundifolia</i>	(Hochst.) Planch.	Malvaceae	7	2	0.11	0.04
14	<i>Ekebergia capensis</i>	Sparrm.	Meliaceae	2	1	0.04	0.02
15	<i>Erythrina abyssinica</i>	Lam. ex DC.	Fabaceae	0	1	0.00	0.02
16	<i>Euclea divinorum</i>	Hiern	Ebenaceae	11	2	0.15	0.04
17	<i>Ficus exasperata</i>	Vahl.	Moraceae	0	1	0.00	0.02
18	<i>Ficus lutea</i>	Vahl.	Moraceae	0	1	0.00	0.02
19	<i>Flueggea virosa</i>	(Roxb. ex Willd.) Royle	Phyllanthaceae	6	7	0.10	0.11
20	<i>Grevillea robusta</i>	A. Cunn. ex R. Br.	Proteaceae	0	11	0.00	0.15
21	<i>Gymnosporia heterophylla</i>	(Eckl. & Zeyh.) Loes.	Celasteraceae	3	0	0.06	0.00
22	<i>Jacaranda mimosifolia</i>	D. Don	Bignoniaceae	8	0	0.12	0.00
23	<i>Leuceana leucocephala</i>	(Lam.) de Wit	Fabaceae	5	2	0.09	0.04
24	<i>Markhamia lutea</i>	(Benth.) K. Schum	Bignoniaceae	0	1	0.00	0.02
25	<i>Montanoa hibiscifolia</i>	Benth	Asteraceae	0	2	0.00	0.04
26	<i>Neubotonia macrocalyx</i>	Pax	Euphorbiaceae	5	1	0.09	0.02
27	<i>Oncoba spinosa</i>	Forssk	Flacourtiaceae	0	2	0.00	0.04
28	<i>Opuntia ficus-indica</i>	(L.) Milli	Cactaceae	0	1	0.00	0.02
29	<i>Osyris lanceolata</i>	Hochst. & Steud.	Santalaceae	24	25	0.25	0.25
30	<i>Ozoroa insignis</i>	Delile	Anacardiaceae	0	1	0.00	0.02
31	<i>Phyllenoptera eriocalyx</i>	(Harms) Schrire	Fabaceae	0	1	0.00	0.02
32	<i>Psychotria riparia</i>	(K. Schum. & K. Krause) Petit	Rubiaceae	2	0	0.04	0.00
33	<i>Searsia longipes</i>	(Engl.) Moffett	Anacardiaceae	0	4	0.00	0.07
34	<i>Searsia natalensis</i>	(Bernh. ex Krauss) F. A. Barkley	Anacardiaceae	10	0	0.14	0.00
35	<i>Searsia vulgaris</i>		Anacardiaceae	0	4	0.00	0.07
36	<i>Senna siamea</i>	(Lam.) H. S. Irwin & Barneby	Fabaceae	15	10	0.19	0.14
37	<i>Senna spectabilis</i>	(DC.) H. S. Irwin & Barneby	Fabaceae	33	14	0.29	0.18
38	<i>Strychnos mitis</i>	S. Moore	Loganiaceae	6	0	0.10	0.00
39	<i>Turraea robusta</i>	Gurke	Meliaceae	15	6	0.19	0.10
40	<i>Vachellia sieberiana</i>	(DC.) Kyal. & Boatwr.	Fabaceae	3	0	0.06	0.00

S/N	Botanical name	Author	Family	TRGTTC	TTTC	H'TRG	H'T
41	<i>Vangueria madagascariensis</i>	J. F. Gmel.	Rubiaceae	0	52	0.00	0.34
42	<i>Vepris simplicifolia</i>	(Engl.) Mziray	Rutaceae	17	0	0.20	0.00
43	<i>Vernonia amygdalina</i>	Del.	Asteraceae	3	2	0.06	0.04
	Total			212	215	2.88	2.76

3.3.4. Shrubs/Woody Climber's Relative Density, and Distribution

During this study, the research team recorded 26 shrubs and woody climbers. Their dense variety among themselves where by few of them were revealed to be the most dense with the

relative density (RD/ha) of ≤ 47.90 - ≥ 10.14 with the IVI of ≤ 59.14 - ≥ 21.38 ; and this category comprised of *Acalypha fruticosa* Forssk, *Lantana camara* L, and *Lippia javanica* (Burm. f.) Spreng. The most distributed shrub/woody climbing plants got the relative frequency (RF) of ≤ 13.48 - 11.24, and those were *Acalypha fruticosa* (Forssk, *Lantana camara* L., and *Lippia javanica* (Burm. f.) Spreng (Table 4).

Table 4. Shrubs/Woody Climber's Relative Density, and Relative Frequency.

S/N	Botanical name	Author	Family	IN	A	IS	TTC	F	H'	D/ha	RF	RD/ha	IVI
1	<i>Acalypha fruticosa</i>	Forssk	Phyllanthaceae	1.0	0.0	0.0	125	12	0.28	1,602.6	13.48	14.57	28.05
2	<i>Acalypha ornata</i>	Hochst. ex A. Rich.	Phyllanthaceae	1.0	0.0	0.0	12	1	0.06	153.8	1.12	1.40	2.52
3	<i>Caesapinia decapetala</i>	(Roth) Alston	Fabaceae	0.0	0.0	0.0	32	7	0.12	410.3	7.87	3.73	11.59
4	<i>Ocimum gratissimum</i>	L.	Lamiaceae	1.0	0.0	0.0	7	1	0.04	89.7	1.12	0.82	1.94
5	<i>Clematis sinensis</i>	Lour.	Ranunculaceae	1.0	0.0	0.0	5	2	0.03	64.1	2.25	0.58	2.83
6	<i>Conyza newii</i>	Oliv. & Hiern	Asteraceae	1.0	0.0	0.0	3	1	0.02	38.5	1.12	0.35	1.47
7	<i>Grewia similis</i>	K. Schum.	Malvaceae	1.0	0.0	0.0	17	3	0.08	217.9	3.37	1.98	5.35
8	<i>Helinus integrifolius</i>	(Lam.) Kuntze	Rhamnaceae	1.0	0.0	0.0	3	1	0.02	38.5	1.12	0.35	1.47
9	<i>Hibiscus micranthus</i>	L. fil	Malvaceae	1.0	0.0	0.0	9	3	0.05	115.4	3.37	1.05	4.42
10	<i>Hoslundia opposita</i>	Vahl.	Lamiaceae	1.0	0.0	0.0	36	7	0.13	461.5	7.87	4.20	12.06
11	<i>Indigofera rynhocarpa</i>	Welw. Ex Baker	Fabaceae	1.0	0.0	0.0	6	2	0.03	76.9	2.25	0.70	2.95
12	<i>Landolphia buechananii</i>	(Hallier f.) Stapf	Apocynaceae	1.0	0.0	0.0	3	1	0.02	38.5	1.12	0.35	1.47
13	<i>Lantana camara</i>	L.	Lamiaceae	0.0	1.0	1.0	411	10	0.35	5,269.2	11.24	47.90	59.14
14	<i>Lippia javanica</i>	(Burm. f.) Spreng.	Lamiaceae	1.0	0.0	0.0	87	10	0.23	1,115.4	11.24	10.14	21.38
15	<i>Microglossa pyrifolia</i>	(Lam.) Kuntze	Asteraceae	1.0	0.0	0.0	10	2	0.05	128.2	2.25	1.17	3.41

S/N	Botanical name	Author	Family	IN	A	IS	TTC	F	H'	D/ha	RF	RD/ha	IVI
16	<i>Microglossa pyropappa</i>	(A. Rich.) Agnew	Asteraceae	1.0	0.0	0.0	12	2	0.06	153.8	2.25	1.40	3.65
17	<i>Monanthes buchananii</i>	(Engl.) Verdc.	Annonaceae	1.0	0.0	0.0	5	1	0.03	64.1	1.12	0.58	1.71
18	<i>Phyllanthus recticulatus</i>	Poir	Phyllanthaceae	1.0	0.0	0.0	2	1	0.01	25.6	1.12	0.23	1.36
19	<i>Plectranthus barbatus</i>	Andrews	Lamiaceae	1.0	0.0	0.0	2	1	0.01	25.6	1.12	0.23	1.36
20	<i>Psiadia punctulata</i>	Vatke	Asteraceae	1.0	0.0	0.0	19	4	0.08	243.6	4.49	2.21	6.71
21	<i>Pterolobium stellatum</i>	(Forssk.) Brenan	Fabaceae	1.0	0.0	0.0	7	1	0.04	89.7	1.12	0.82	1.94
22	<i>Rhoicissus tridentata</i>	(L. f.) Wild & R. B. Drumm.	Vitaceae	1.0	0.0	0.0	2	1	0.01	25.6	1.12	0.23	1.36
23	<i>Rotheca myricoides</i>	(Hochst.) Steane	Verbenaceae	1.0	0.0	0.0	7	3	0.04	89.7	3.37	0.82	4.19
24	<i>Senna bicapsularis</i>	(L.) Roxb	Fabaceae	0.0	1.0	0.0	14	7	0.07	179.5	7.87	1.63	9.50
25	<i>Toddalia asiatica</i>	(L.) Lam	Rutaceae	1.0	0.0	0.0	12	3	0.06	153.8	3.37	1.40	4.77
26	<i>Vernonia sp</i>		Asteraceae	1.0	0.0	0.0	10	2	0.05	128.2	2.25	1.17	3.41
	Total			23.0	2.0	1.0	858	89	2.00	11000	100	100	200
	Percentage			88.5	7.7	3.8							

3.3.5. Herbaceous Plants Species Mean Percentage Cover and Distribution

The highest mean percentage cover (MPC) was recorded for *Ageratum conyzoides*, *Bidens pilosa*, *Dichanthium*

flaveolatum (MPC = ≤ 10.19 - ≥ 5.19). Those with the MPC < 5.19 were judged as the least covering taxa. The most distribute herbaceous plant species got the relative frequency (RF) of ≤ 10.77 - ≥ 8.46 ; and was occupied by *Ageratum conyzoides*, and *Bidens pilosa* L (Table 5).

Table 5. Herbaceous Plant Species Mean Percentage Cover and Relative Frequency.

S/N	Botanical name	Author	Family	IN	A	IS	PC	MPC	F	RF
1	<i>Acalypha volkensii</i>	Pax	Phyllanthaceae	1	0	0	20	0.77	2	1.54
2	<i>Acanthospermum hispidum</i>	DC	Asteraceae	0	1	1	15	0.58	1	0.77
3	<i>Acmella uliginosa</i>	(Swartz.) Cass	Asteraceae	1	0	0	15	0.58	2	1.54
4	<i>Ageratum conyzoides</i>	L.	Asteraceae	0	1	1	265	10.19	14	10.77
5	<i>Argemone mexicana</i>	L.	Papaveraceae	0	1	1	5	0.19	1	0.77
6	<i>Aristida adscensionis</i>	L.	Poaceae	1	0	0	50	1.92	3	2.31
7	<i>Asparagus racemosus</i>	Willd.	Asparagaceae	1	0	0	30	1.15	3	2.31

S/N	Botanical name	Author	Family	IN	A	IS	PC	MPC	F	RF
8	<i>Bidens pilosa</i>	L.	Asteraceae	1	0	0	200	7.69	11	8.46
9	<i>Chamaecrista mimosoides</i>	(L.) Greene	Fabaceae	1	0	0	5	0.19	1	0.77
10	<i>Chloris pycnothryx</i>	Trin	Poaceae	1	0	0	60	2.31	2	1.54
11	<i>Cissus rotundifolia</i>	Lam	Vitaceae	1	0	0	25	0.96	3	2.31
12	<i>Clinopodium abyssinicum</i>	(Benth.) Kuntze	Lamiaceae	1	0	0	15	0.58	1	0.77
13	<i>Commelina benghalensis</i>	L.	Commelinaceae	1	0	0	140	5.38	5	3.85
14	<i>Crotalaria pallida</i>	Aiton	Fabaceae	1	0	0	5	0.19	1	0.77
15	<i>Cynodon dactylon</i>	(L.) Pers	Poaceae	1	0	0	10	0.38	1	0.77
16	<i>Cyphostemma adenocaulis</i>	(Steud. ex A. Rich.) Desc. ex Wild & R. B. Drumm.	Vitaceae	1	0	0	15	0.58	2	1.54
17	<i>Desmodium salicifolium</i>	(Poir.) DC	Fabaceae	1	0	0	65	2.50	2	1.54
18	<i>Dichanthium flaveolatum</i>	(Delile) Roberty	Poaceae	1	0	0	135	5.19	3	2.31
19	<i>Digitaria abyssinica</i>	(Hochst. ex A. Rich.) Stapf	Poaceae	1	0	0	45	1.73	4	3.08
20	<i>Erigeron bonariensis</i>	L.	Asteraceae	0	1	1	60	2.31	2	1.54
21	<i>Euphorbia heterophylla</i>	L.	Euphorbiaceae	0	1	1	10	0.38	2	1.54
22	<i>Euphorbia hirta</i>	L.	Euphorbiaceae	1	0	0	5	0.19	1	0.77
23	<i>Hibiscus cannabinus</i>	L.	Malvaceae	1	0	0	15	0.58	1	0.77
24	<i>Indigofera atriceps</i>	Hook. f.	Fabaceae	1	0	0	20	0.77	2	1.54
25	<i>Jasminum fluminense</i>	Vell.	Oleaceae	1	0	0	10	0.38	1	0.77
26	<i>Justicia flava</i>	(Forssk.) Vahl.	Acanthaceae	1	0	0	10	0.38	1	0.77
27	<i>Justicia striata</i>	(Klotzsch.) Bullock	Acanthaceae	1	0	0	120	4.62	2	1.54
28	<i>Kalanchoe densiflora</i>	Rolfe	Crassulaceae	1	0	0	15	0.58	2	1.54
29	<i>Leucas grandis</i>	Vatke	Lamiaceae	1	0	0	55	2.12	5	3.85
30	<i>Melhania velutina</i>	Forssk.	Malvaceae	1	0	0	10	0.38	2	1.54
31	<i>Melinis repens</i>	(Willd.) Zizka	Poaceae	1	0	0	30	1.15	2	1.54
32	<i>Momordica foetida</i>	Schum.	Cucurbitaceae	1	0	0	25	0.96	2	1.54
33	<i>Neorautanenia mitis</i>	(A. Rich.) Verdc	Fabaceae	1	0	0	100	3.85	3	2.31
34	<i>Nicandra physaloides</i>	(L.) Gaertn.	Solanaceae	0	1	1	5	0.19	1	0.77
35	<i>Ocimum gratissimum</i>	L.	Lamiaceae	1	0	0	25	0.96	3	2.31
36	<i>Osplismamus hirtellus</i>	(L.) Beauv.	Poaceae	1	0	0	95	3.65	1	0.77
37	<i>Oxalis corniculata</i>	L.	Oxalidaceae	1	0	0	40	1.54	2	1.54
38	<i>Oxalis latifolia</i>	Kunth	Oxalidaceae	1	0	0	40	1.54	2	1.54
39	<i>Oxygonum sinuatum</i>	(Hochst. & Steud. ex Meisn.) Dammer	Polygonaceae	1	0	0	10	0.38	1	0.77
40	<i>Panicum maximum</i>	Jacq.	Poaceae	1	0	0	20	0.77	2	1.54
41	<i>Pellaea longipilosa</i>	Bonap.	Adiantaceae	1	0	0	80	3.08	4	3.08
42	<i>Rhynchosia sublobata</i>	(Schumach.) Meikle	Fabaceae	1	0	0	75	2.88	2	1.54

S/N	Botanical name	Author	Family	IN	A	IS	PC	MPC	F	RF
43	<i>Richardia brassihensis</i>	Gomes	Rubiaceae	0	1	1	35	1.35	2	1.54
44	<i>Salvia nilotica</i>	Juss. ex Jacq	Lamiaceae	1	0	0	5	0.19	1	0.77
45	<i>Schukuhria pinnata</i>	(Lam.) Thell.	Asteraceae	0	1	1	55	2.12	3	2.31
46	<i>Secamone punctulata</i>	Decne	Apocynaceae	1	0	0	15	0.58	1	0.77
47	<i>Sida acuta</i>	Burm. f.	Malvaceae	1	0	0	45	1.73	3	2.31
48	<i>Solanecio angulatus</i>	(Vahl) C. Jeffrey	Asteraceae	1	0	0	50	1.92	2	1.54
49	<i>Solanum campylacanthum</i>	Hochst. ex A. Rich.	Solanaceae	1	0	0	12	0.46	2	1.54
50	<i>Sonchus schweinfurthii</i>	Oliv. & Hiern	Asteraceae	1	0	0	5	0.19	1	0.77
51	<i>Sporobolus pyramidalis</i>	P. Beauv.	Poaceae	1	0	0	15	0.58	1	0.77
52	<i>Tephrosia villosa</i>	(L.) Pers.	Fabaceae	1	0	0	15	0.58	2	1.54
53	<i>Tridax procumbeus</i>	L.	Asteraceae	0	1	1	35	1.35	3	2.31
54	<i>Triumfetta rhomboidea</i>	Jacq.	Tiliaceae	1	0	0	15	0.58	1	0.77
Total				45	9	9	2297	88.35	130	100
Percentage				83.3	16.7	16.7				

3.4. Alien and Invasive Plants

Out of the recorded 113 plant species including herbaceous (54), trees (33), and shrubs (26), only 16 of them (14.2%) were alien, while 14 of them (12.4%) were alien invasive (Tables 2-6).

Table 6. Indigenous, alien and alien invasive plants per growth form.

Growth form	Tree species recorded	Indigenous	Alien	Invasive
Herbaceous	54	45	9	9
Shrub (s)	26	23	2	1
Tree (s)	33	28	5	4
Total	113	96	16	14
Percentage	100	85.0	14.2	12.4

The densest alien invasive plant species was recorded in the group of shrubs/wood climbers, *Lantana camara* L. with the IVI of 59.14 (Table 5).

4. Discussion

The described habitats at the eastern ridge of Duluti Lake Catchment forest are importantly diverse in terms of plant species. The bush lands have sparse flora with 10 – 40% cover of trees, bushes and shrubs harboring biological species [22]. It has been stated that bush lands or shrub land harbor

significant diverse of plant species [38, 50]. Woodland are characterized by trees with crowns not forming a thick continuous canopy, and the features of this vegetation include grasses and herbs as dominant ground cover where epiphytes and ferns are rare but lichens may be present [1]. The recorded 113 plant species (Table 1) with the calculated H' of 2.0 for shrubs (Tables 1 and 4), and 2.8 for trees (Tables 1, 2; and Figure 3), and tree regeneration (Table 3), from both bush/shrub land (Figure 2) and woodland (Figure 3) implied high plant species diversity.

The growth form with high species implied high percentage too (Figure 4).

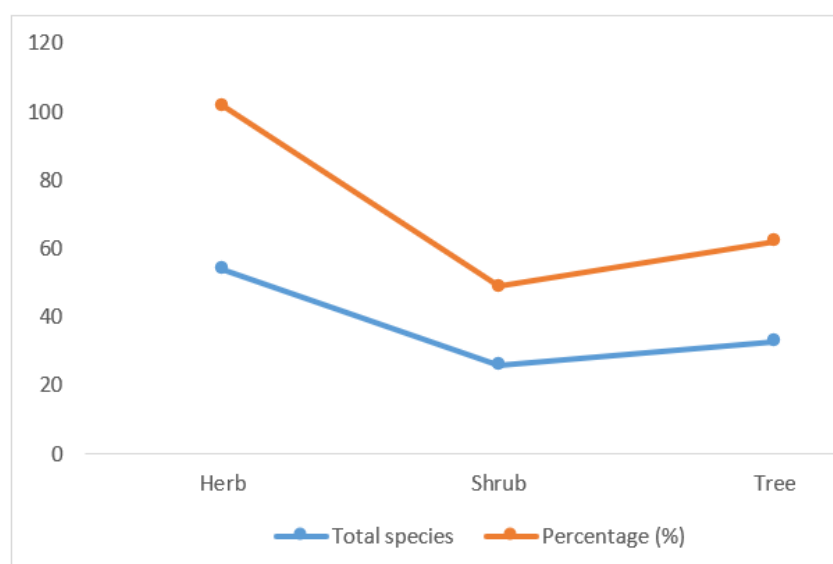


Figure 4. Total Plant Species Recorded at Eastern Ridge of Duluti Catchment Forest Reserve and Their Percentage.

The computed H' of $\leq 3.5 - \geq 1.5$, indicates high diversity, even though exceptionally the calculated H' can go beyond 3.5 [49, 18]. The recorded highest number of mature tree level reveals that most trees were mature but lacking the future replacement [30]. On the other hand, under *ceteris paribus* (all other conditions being constant), those mature trees with

recorded regeneration were in the position of future existence when the mature trees die or disappear, while the rest 10 species were only at regeneration level (Table 8), an implication of having been emerged from the prevailed seed bank or sprouting after death of old mature trees.

Table 8. Total Species Per Tree Growth Level.

Category	Total plant species	Percentage (%)
Both regeneration and mature tree level	16	37.2
Mature trees level only	17	39.5
Tree regeneration level only	10	23.3
Total	43	100

The highest IVI for an alien invasive plant species, *Lantana camara* L., indicates that the eastern side ridge is dominated by exotic species thus altering the natural scenery of the area. Studies by Boy and Witt [9], and Boadie-Ampong and Nishi [7], revealed that alien invasive plants species distort the natural state of the ecosystem. Additionally, the invasion of plant species is considered to be one of the most dangerous forces in biodiversity change and alteration of soil properties [8]. The relative frequency highlights the level of spreading of a species, hence the one with the highest RF is countered as the most occurring species, thus contributing IVI, as among determinants of the dominating species in a particular location's ecosystem [10]. The Importance Value Index (IVI) is a quantitative measure used in ecology to assess the relative importance of a species within a community by combining

multiple parameter [44]. On the other hand, the relative frequency (RF) in ecology is a measure of the dispersion or spatial distribution of a species within a given area, which indicates how common or widespread it is, but it does not directly measure the species' density or the vigor of its land occupation [31].

Invasive plant species can cause negative impacts to native plants [45]. Alien invasive trees can discourage the germination of seeds and growth rate of all plant forms in the ecosystem, while shrubs and woody climbers alien invasive plants can affect most young trees (regeneration), and herbaceous plants together with their seed bank [52]. On the other hand, alien invasive herbaceous plants mostly affect their fellow native herbaceous plants and even their either being alien invasive or not invasive is mostly noticeable when

comparing with the native plants densities, and distribution [35]. Furthermore, Alien invasive plants can harbor pests that were not existing previously, become weed of cultivation, influence severe competition towards soil nutrients, reduce pastures, and also spoiling natural scenery [5, 37].

In terms of conservation sustainability, natural vegetation is considered to have been distorted when alien invasive plants are severely spreading throughout natural environment [8, 21]. The protected areas that are also important as tourism industry are expected to attract customers, when they are free from alien invasive composition [34]. Witt and Luke [48], explained that alien plant species such as *Cedrella odorata* L. have become invasive in Amani Nature Reserve. The highest IVI (59.14) for *Lantana camara* L. implied how invasive was the taxa in the area. Witt and Luke [48], pinpointed that *L. camara* L. is a serious weed on roadsides and secondary vegetation, and it mostly escape from settlements and institutions buildings where it was introduced to tropical countries from Bahamas, Colombia, Costa Rica, Cuba, Hispaniola, Jamaica, Mexico, and Venezuela as an ornamental [48].

5. Conclusions and Recommendations

5.1. Conclusions

Plant species composition and structure are viewed as vital entities for the management of forest reserves. On the other hand, invasive alien plant species (IAS) are known for their negative impacts especially when they massively spread beyond their natural habitats overwhelming the indigenous plant species. The high diversity of indigenous plant species at eastern ridge of Duluti Lake Catchment Forest Reserve is intimidated by IAS while the botanical investigation remains inadequately done.

5.2. Recommendations

There may be many recommendations, however, the research team among others, sets the following recommendations:

- 1) Further research on plant species composition and structure dynamics is needed
- 2) Evaluate the alien invasive plants throughout the Duluti Catchment Forest Reserve
- 3) Remove and replace the IAS with indigenous plants
- 4) Regular monitoring and removing any IAS seedlings
- 5) Limit any human activities leading to excavation and removal of indigenous plants
- 6) Any seeds from edible alien plants should be kept in dust bins and disposed at specified dumps

Abbreviations

A	Alien
D/Ha	Density per Hectare
DLCFR	Duluti Lake Catchment Forest Reserve
F	Frequency
H'	Shannon Weaner Diversity Index
H'	Shannon Weaner Diversity Index Total
H'TRG	Shannon Weaner Diversity Index Total for Tree Regeneration
IAS	Invasive Alien Species
IN	Indigenous
IS	Invasive
IVI	Importance Value Index
MNRT	Ministry of Natural Resources and Tourism
MPC	Mean per centage Cover
PC	Percentage Cover
RF	Relative Frequency
RD/Ha	Relative Density per Hectare
RF	Relative Frequency
TRGTTC	Tree Regeneration Total Count
TTTC	Tree Total Count

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Conflicts of Interest

The author has no conflicting interest with this publication.

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