

Impact of *Lantana camara* on plant diversity and composition in Dara, Mirab Abaya, and Dila Zuria, Ethiopia

¹Amare Seifu, ²Ermias Lulekal & ³Melese Bekele

Abstract

Lantana camara (*L.camara*) has been ranked as the top impacting invasive alien plant species. However, its impacts have not been well studied in Ethiopia. Therefore, the objective of this study was to investigate the impact of *L.camara* on species diversity and composition of invaded plant communities in three districts of Ethiopia. A total of 120 (60 plots for each invaded and non-invaded), 10mX10m plots were sampled to examine its effects of invasions on the diversity and composition of invaded plant communities. A total of 109 plant species were found in the non-invaded areas as compared to 56 in invaded areas. The plant species richness decreased by 48.6% in *L.camara* invaded areas as compared to non-invaded. The mean evenness values of the entire invaded sampled study site and that of non-invaded were 0.24 and 0.81 respectively. Thus, the heterogeneity of invaded study sites was reduced by 57%. The number of plant families was 44 in the non-invaded areas in contrast to only 30 in invaded areas. The number of plant families decreased by 31.8% in the invaded areas as compared to non-invaded. One-way ANOVA, regression, and ordination analyses also showed a strong negative relationship between the percentage of *L.camara* and diversity of plant species. Therefore, it was noted that *L.camara* has a serious impact on plant species diversity and composition. Hence, the finding calls for an urgent management and control strategy against the spread of *L.camara* so as to save the ongoing threat to biodiversity.

Keywords: composition, evenness, infestation-levels, invaded plant communities, richness

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1. Introduction

Invasive alien species (IASs) are among the major threats to the world's biodiversity, health, and economic sustainability; especially in the case of developing countries (Bodey *et al.*, 2022; Rawat *et al.*, 2024). Causing harm to almost every ecosystem worldwide, the economic impacts attributable to IASs are anticipated to worsen as a result of the dynamic climatic changes (Duboscq-Carra *et al.*, 2021; Kumar *et al.*, 2024; Angulo *et al.*, 2021; Jamadar *et al.*, 2025). Currently, IASs globally cause estimated damages of an impressive £1.5 trillion every year; which makes up an alarming 5% of the world's gross domestic product (Pimentel *et al.*, 2005). This effect is graver in the developing economies because of the central role of agriculture in their gross domestic products (Araos *et al.*, 2020; Belbase & Ghimire, 2021; Stewart *et al.*, 2021).

Globalized trade, transportation, and tourism have also led to the rapid intentional and unintentional range extension of organisms (Gulzar *et al.*, 2024). These include the invasive alien plant species (IAPSs) that have entered the native habitats, leading to the displacement of native plants in their habitat niche (Banerjee & Sati, 2026). One among them is *Lantana camara* (*L.camara*), which is native to the Caribbean and the Latin American region. It is also known as one of the most aggressive forms of the IAPSs, as it is presently endangering more than 60 countries (Barik *et al.*, 2020). The distribution and density are increasing globally, which is disturbing the balance in the ecosystem (Sharma *et al.*, 2005; Singh *et al.*, 2025).

The global spread of *L.camara* has been attributed to its ability to flourish on poor soils and in unshaded environments, including degraded pastures, forest edges, and riparian zones (Sharma *et al.*, 2005; Dyderski & Jagodzin'ski, 2020). In Ethiopia, IAPSs are spreading fast and pose critical threats to biological diversity and economic stability. *L.camara* has successfully invaded different Ethiopian landscapes, from cultivated fields and riverbanks to urban centers (Bekele, 2018). As it obstructs vital infrastructure, such as irrigation canals, directly undermining sustainable development, poverty alleviation, and food security, the need for management becomes increasingly important (Gebrewahid *et al.*, 2025). Consequently, management of *L.camara* is essential to maintaining ecological health and supporting livelihoods in rural communities of Ethiopia.

Invasive species are recognized as a serious problem in Ethiopia's Environmental Policy and National Biodiversity Strategy and Action Plan. While *Parthenium hysterophorus*, *Prosopis juliflora*, and *Eichhornia crassipes* are important invasive plants in the country,

L.camara is one of the most harmful invasive plants in the country (Worku & Gasheye, 2025). Biologically, its success is attributed to its reproductive ability; it can produce up to 12,000 seeds from a single individual in a year and the seeds remain viable even after several years (Barik *et al.*, 2020; Hansda *et al.*, 2024). Moreover, once the plant establishes, it grows in dense thickets that outcompete indigenous plants, thereby outgrowing their environmental role in the country. In addition, the plant has the mechanism to recover from shoot deaths, which greatly enhances its lifespan (Gebrewahid *et al.*, 2025).

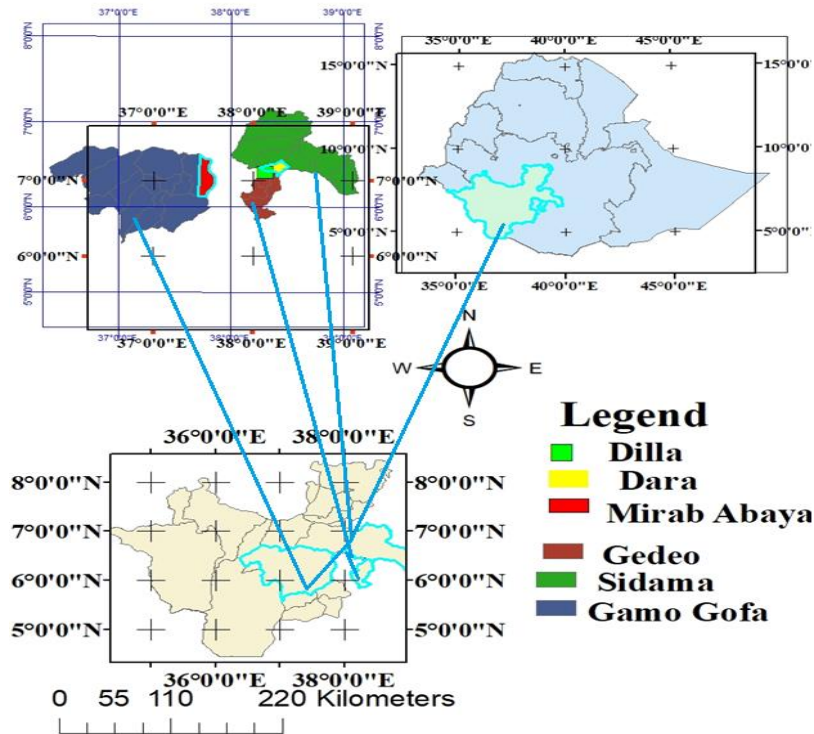
Although *L.camara* is documented as one of the most important threats to biodiversity and the economy of Ethiopia, there are still significant knowledge gaps regarding its status and impacts in the country. Whereas its potential to infest rangelands and irrigation systems is well noted (Bekele, 2018), detailed information regarding the incidence of this IAPS and its impact on plant species diversity and composition within the Dara, Mirab Abaya, and Dila Zuria districts is currently not available. This study, therefore, intends to determine how *L.camara* affects the diversity and composition of invaded communities within these regions. Such information would be important in order to develop focused management strategies aimed at maintaining regional floristic integrity.

2. Materials and Methods

2.1. Description of the Study Areas

The study was conducted in Dila Zuria districts (from Gedio zone), Mirab Abaya (from Gamagofa) and Dara (from Sidama). Gedio zone is surrounded by Oromia region in the south, southwest, and Abaya district in the northwest and east directions, and Sidama region in north direction. It roughly lies between 6°59'-6°62" north, latitude and 38°40'-38°43" east longitude. The capital is Dilla town which is located 365km from Addis Ababa. The altitude ranges from 1500 to 3000 meter above sea level and has a total estimated area of 1,354sq.km (Gedeo Zone Finance and Economic Development office, 2016) as shown in Figure 1.

The Gamo-Gofa Zone is named for the Gamo and Gofa peoples. It is bordered by Dirashe, Debub Omo, Basketo, Konta, Dawro, Wolayita, Lake Abaya, and Amaro. Its administrative center is Arba Minch. Sidama is bounded by Oromia, the Gedieo Zone, and Wolayita. Located between 6°14'–7°18'N and 37°92'–39°14'E, its elevation ranges from 1,500 to 2,500 meters. The capital, Hawassa, is 273 km from Addis Ababa. The region covers 6,981.8 sq km (Iqbal *et al.*, 2023).

Figure 1*Administrative map of the study area*

2.2. Materials

The common equipment and tools used in voucher specimen collection during the study were field press, newspapers, plastic bags, pencils, camera, measuring tape, diggers, blotters, GPS, study location and documentation data form.

2.3. Method of Data Collection

This study was conducted between April 2020 and March 2021 in Mirab Abaya (from Gamogofa), Dilla Zuria (from Gedio) and Dara (from Sidama) districts, Ethiopia. The study zones and districts were selected purposively on the basis of the level of *L.camara* invasion with the help of information obtained from agricultural office of each study areas. Based on the selection criteria, from the three study area, three districts were selected. Mirab Abaya, Dilla Zuria and Dara districts were selected from Gamo-Gofa, Gedio and Sidama, respectively. From each district one kebele (the smallest administrative unit in Ethiopia) was selected. From Mirab Abaya, Woze Kebele was selected while from Dara and Dilla zuria Mechisho and Waleme kebele were selected, respectively. In each kebele, community forest areas (*L. camara* invaded community forests) were selected. Accordingly, Woze, Mechisho and Waleme kebele

community forests were selected. The impact of *L. camara* on the species diversity and composition of invaded plant communities was studied by applying Quadrat Method following (Kumar *et al.*, 2025, Haubrock *et al.*, 2021, Singh *et al.*, 2025).

2.4. Plot Selection

A total of 120 plots, 10m × 10m in dimension, were employed in studying the effects caused by *L.camara* on the diversity and composition at the invaded sites. A stratified systematic sampling method was employed in which 60 plots were sampled from the invaded areas and 60 from the non-invaded (control) areas. A total of 40 plots in each of the three districts was replicated (20 in the invaded and 20 in the non-invaded). To further analyze the degree of invasion, the invaded plots were categorized into three levels: low invasion level, medium invasion level, and high invasion level. Fifteen plots were allocated to each level for analysis through one-way ANOVA.

Using a modified Daubenmire (1959) cover-abundance method, this study assessed *L.camara* coverage across 10 m × 10 m plots. This quadrat size was selected over the original 20 cm × 50 cm dimensions to better accommodate the species' shrubby growth patterns. Visual estimations assigned vegetation to one of six standard cover classes.

Following frameworks by De Stefano *et al.* (2021) and Katembo *et al.* (2022), sample sites were categorized into three distinct invasion levels based on total percentage area coverage: low (0–25%), medium (26–50%), and high (> 50%). This classification system allows for a standardized analysis of how varying densities of *L.camara* influence associated species diversity and ecosystem structure. By adapting the sample unit size while maintaining the rigorous six-class estimation scale as shown in Table 1, the methodology ensures ecological relevance to the specific architecture of the invaded Ethiopian landscape.

Table 1

Cover was categorized into six classes

Cover Class	Range of Coverage (%)	Midpoint (%)
1	0 – 5	2.5
2	5 – 25	15.0
3	25 – 50	37.5
4	50 – 75	62.5
5	75 – 95	85.0
6	95 – 100	97.5

Vegetation sampling was conducted twice, once during the late rainy season-peak of flowering-to capture annual growth and once during the late dry season, with the purpose of accounting for seasonal variation. The dual-season sampling allows for comprehensive data on species composition regardless of climatic changes throughout the year (Kumar *et al.*, 2025).

In each selected study Kebele, one plot of the pair was placed in severely invaded plant communities (“invaded plots”) where the invader was dominant and had a high cover, and the second plot was placed in neighboring plant community where *L.camara* had no cover (“non-invaded plots”) purposively. As much as possible, the non-invaded plot was chosen to have as similar site conditions (<10 m) to the invaded plot to minimize environmental variance, all plots were selected in close proximity within the same ecological zones and topographical conditions following Barahukwa *et al.* (2023), Haines *et al.* (2024) and Najberek *et al.* (2024). The location of each plot and study sites were recorded with GPS.

A non-invaded area was selected so as to compare the species richness, evenness and composition of vegetation in the invaded and non-invaded areas. All the plant species appeared in the invaded and non-invaded areas were sampled and identified. The majority of the species found in the quadrats was identified in the field. For species difficult to identify in the field, voucher specimens were collected, pressed and dried properly and transported to Ethiopian Biodiversity Institute for identification and proper naming. The nomenclature of the plant species followed the Flora of Ethiopia and Eritrea.

2.5. Method of Data Analysis

The collected data was analyzed by using R-package (version 4.2). A descriptive statistical method was employed to analyze and summarize the data. Inferential statistical method was also employed. Linear Regression Analysis was used to predict the value of a variable based on the value of another variable. The percentage and number of *L.camara* per study site and per quadrat was taken as the independent variables while richness and evenness of plant species were taken as the dependent variable.

The collected data for the study were subjected to a one-way ANOVA for each constraint (infestation level) to establish differences among the plant species richness means. Significance levels among treatment means were compared using Tukey’s Honestly Significant Difference (HSD) Test at a 5% level of significance to find out which groups were considerably different from one another (low infestation level to high, medium, and high to

medium). Data were also statistically analyzed by PCA to extract the significant correlations from species data set or the correlation between a row (site/plots) and a column (the plant species/variable).

2.6. Vegetation Analysis

Plant species diversity analysis (Shannon 1949, H') and richness and evenness ($E = H'/H'_{\max}$) of each study sites was analyzed. Evenness was calculated as $H'/\ln S$, where S is the species richness expressed as the number of species (Najberek *et al.*, 2024). Differences in species richness S , Simpson (1-D) index diversity, Shannon index of diversity H' and evenness between invaded and non-invaded plots were used to measure the effect of invasion on these plant communities' characteristics.

The Simpson index of dominance is calculated using the formula $D = \sum [n_i(n_i-1)] / [N(N-1)]$; $1-D$ is Simpson's Index of diversity, where D = Simpson's dominance index, n_i is the number of individuals in the i^{th} plant species and N is the total number of individuals of all species. The value of D ranges between 0 and 1 with this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D , the lower the diversity. On the other hand, D is often subtracted from 1 to give Simpson's Index of Diversity or $1-D$. Therefore, the value of Simpson's Index of Diversity ($1 - D$) also ranges between 0 and 1, but now, the greater the value, the greater the sample diversity (Barrantes & Sandoval, 2009). The species richness S was taken as a measure of diversity at the plot scale. For invasive species studied, the total numbers of species recorded in all plots with invaded and non-invaded vegetation was used as a measure of the impact of invasion on diversity of the plants or species richness, diversity and evenness indices of invaded and non-invaded areas were calculated and compared to find out the loss due to invasion of *L.camara*.

3. Results

3.1. Impact of *L.camara* on Species Evenness and Richness

In the present study, a total of 109 species were found in the non-invaded areas as compared to 56 in *L.camara* invaded areas. The number of species decreased by 48.6% in the *L.camara* invaded areas as compared to the non-invaded areas. In addition, Simpson (1-D) and Shannon (H') of indices diversity, Margalef's index of species richness, and evenness index

were reduced by 66.04%, 74.48%, 51.95% and 57%, respectively in the *L. camara* invaded areas as shown in Table 2.

The mean evenness value of the entire invaded sampled study sites was 0.24 indicated that 24% of the plant communities had uniform distribution while the mean evenness value of the entire non-invaded samples was 0.81 indicated that 81% of the plant communities had uniform distribution. Thus, the heterogeneity of the invaded study sites was reduced by 57%.

Table 2

Impact of L.camara (% decrease over non-invaded) on the plant communities

No.	Parameters	Non-invaded	Invaded	% decrease over non-invaded
1.	Richness (Total Species)	109	56	48.6
2.	Simpson's Index of diversity (1-D)	0.9627	0.3269	66.04
3.	Shannon's Index of Diversity (H')	3.806	0.9712	74.48
4.	Margalef Index of Richness(R)	12.99	6.241	51.95
5.	Index of Evenness (Es)	0.8113	0.2413	57

From the study districts, Dara (Mechisho community forest) was severely affected by the invasion of *L.camara*. In this Kebele community forest, the number of species decreased by 66.15% in the *L.camara* invaded area as compared to the non-invaded areas. Further, Simpson(1-D) and Shannon(H') indices of diversity, Margalef's index of species richness, and evenness index were reduced by 78.44%, 83.99%, 70.16% and 78.39%, respectively in the *L.camara* invaded areas as compared to the non-invaded as indicated in Table 3. Regarding Woze kebele community forest, the number of species decreased by 52.94% in the *L.camara* invaded area as compared to the non-invaded area. In addition, Simpson(1-D) and Shannon(H') indices of diversity, Margalef's index of species richness, and evenness indices were reduced by 65%, 68.55%, 54.49% and 60%, respectively in the *L.camara* invaded areas as compared to the non-invaded. On the other hand, Dilla Zuria (Waleme community forest) was the least affected by the invasion of *L.camara*. In this areas, the number of species decreased by 31.48% in the *L.camara* invaded area as compared to the non-invaded. Moreover, Simpson(1-D) and Shannon(H') indices of diversity, Margalef's index of species richness, and evenness indices were reduced by 32.89%, 47.83%, 31.78% and 42.36%, respectively in the *L.camara* invaded areas as compared to non-invaded.

Generally, a decrease in the *L.camara* invaded area as compared to the non-invaded area on the plant species richness, Simpson(1-D) and Shannon(H') indices of diversity, Margalef's index of species richness and evenness index were highest in Mechisho kebele followed by Woze and Waleme kebeles, respectively.

Table 3

Decrease in the L.camara invaded area as compared to the non-invaded on the plant diversity indices in each of the study Kebele

Name of	Parameters	non-invaded	Invaded	% decrease over non-invaded
Woze	C	34	16	52.94
	1-D	0.8729	0.3051	65.05
	'H'	2.44	0.7674	68.55
	R	4.261	1.854	56.49
	E	0.692	0.2768	60
Waleme	C	54	37	31.48
	1-D	0.9131	0.6127	32.89
	'H'	2.992	1.561	47.83
	R	7.231	4.933	31.78
	E	0.75	0.4323	42.36
Mechisho	C	65	22	66.15
	1-D	0.9565	0.2062	78.44
	'H'	3.604	0.5769	83.99
	R	8.828	2.634	70.16
	E	0.8634	0.1866	78.39

Note: Richness(C); Simpson's Index of Diversity (1-D); Shannon's Index of Diversity (H'); Margalef Index of Richness(R); Index of Evenness (E)

3.2. One-Way Analysis of Variance on Plant Species Richness Versus Infestation Levels of L.camara

The outcomes of the study indicated that the infestation of *L.camara* had great impacts on plant species richness. Generally, as the infestation levels of *L.camara* increased, its impacts on other plant species had also increased. Accordingly, the highest mean number of plant species was identified in low infestation level (18.87~19) followed by medium infestation (9.67~10). Contrary, the minimum mean number of plant species was identified in high

infestation level (4.87~5). Hence, the mean number of plant species in high infestation level of *L.camara* declined by 74.19%, compared to the low infestation level as shown in Table 4.

Table 4

Effects of L.camara infestation on species richness (Mean ± standard error)

Invasion levels of <i>L.camara</i>		N	Mean
Richness	Low	15	18.87±1.01
	Medium	15	9.67±1.28
	High	15	4.87±0.61
	Total	45	11.13±1.04

Based on the outcome of one-way ANOVA, there were variations in the plant species richness across various infestation levels of *L.camara*. Therefore, the result showed that *L.camara* had a substantial ($P \leq 0.001$) impact on plant species richness as shown in Table 5.

Table 5

One-way ANOVA on the impacts of L.camara on plant species richness across various infestation levels

			df	Mean Square	F	Sig.
(Combined)			2	759.200	49.916	0.000
Between Groups	Linear	Contrast	1	1470.000	96.650	0.000
	Term	Deviation	1	48.400	3.182	0.082
Within Groups			42	15.210		
Total			44			

In addition, according to Tukey's HSD test, the level of invasion of *L.camara* (low, medium and high) had different impact on plant species richness. Hence, in all the three infestation levels of *L.camara*, the richness were significantly different from each other (low and medium($p \leq 0.01$), low and high ($p \leq 0.001$), medium and high ($p \leq 0.01$) as indicated in Table 6. Therefore, the plant species richness was highly dependent on infestation levels of *L.camara* which showed a decrease in diversity of plant species as infestation levels increase from low to high.

Table 6

Tukey's HSD test to compare the variation in α -diversity indices among the three infestation levels of *L.camara*

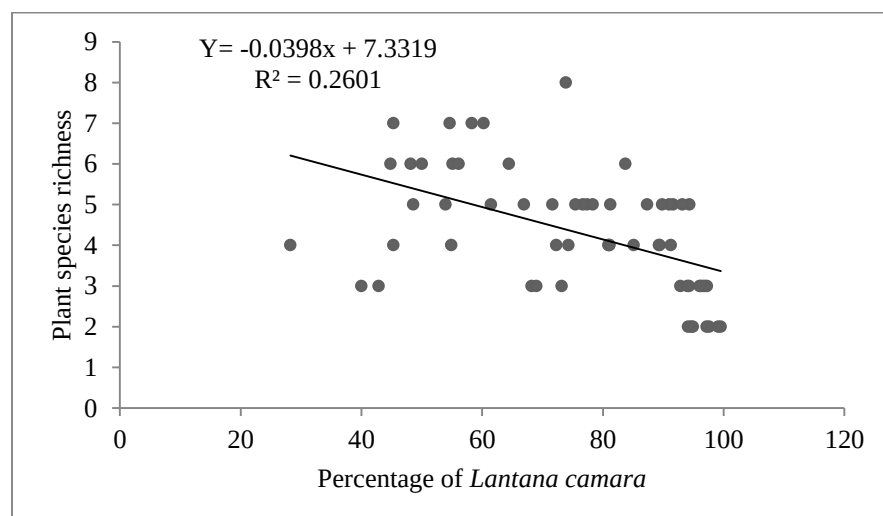
Dependent Variable	Infestation levels (I)	infestation levels (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Richness	Low	Medium	-4.8000*	1.4241	0.005	-8.260	-1.340
		High	-14.0000*	1.4241	0.000	-17.460	-10.540
	Medium	Low	4.8000*	1.4241	0.005	1.340	8.260
		High	-9.2000*	1.4241	0.006	-12.660	-5.740
	High	Low	14.0000*	1.4241	0.000	10.540	17.460
		Medium	9.2000*	1.4241	0.006	5.740	12.660

3.3. Relationship Between Percentage of *L.camara* and Species Richness and Evenness

The regression analysis showed a negative relationship between the percentage of *L.camara* and species richness per quadrat. Hence, the regression equation can be presented as: $Y = -0.0398X + 7.3319$, where Y is species richness and X is percentage of *L.camara* per quadrat which indicated that there was a negative relationship between the percentage of *L.camara* and species richness. As percentage of *L.camara* increased species richness decreased as specified in Figure 2. In this case, $R^2 = 0.2601$ or 26.01% of the dependent variable (species richness) can be explained by the independent variable (percentage of *L.camara*).

Figure 2

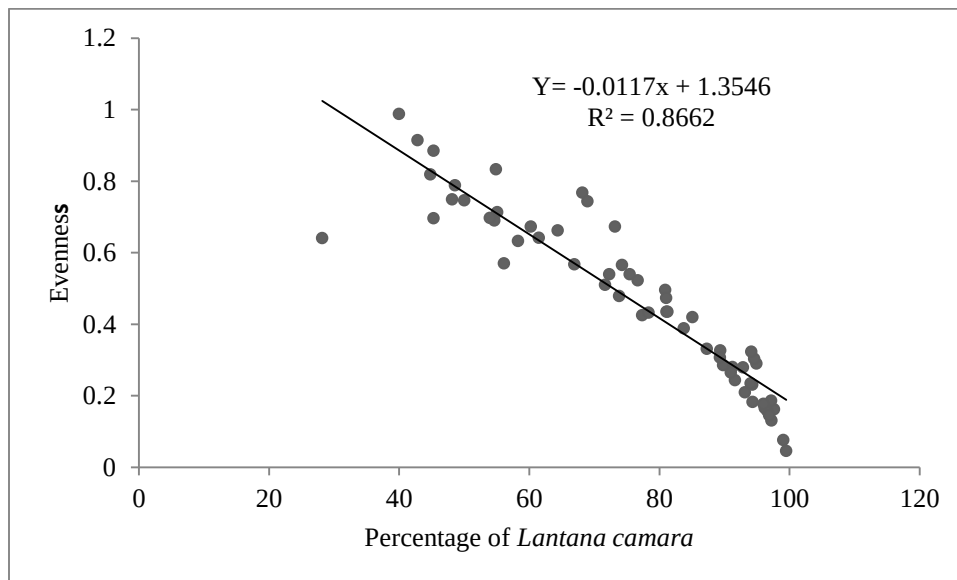
The link between percentage of *L.camara* and species richness per invaded quadrat ($R^2 = 0.2601, p < 0.01$).



The results indicated that there was also strong negative linear relationship between the percentage of *L.camara* and evenness of plant species per quadrat. Hence, the regression equation can be presented as: $Y = -0.0117X + 1.3546$, where Y is evenness and X is percentage of *L.camara* per study quadrat. In this case, $R^2 = 0.8662$, or 86.62% of the dependent variable (species evenness per study quadrat) can be explained by the independent variable (coverage of *L.camara*) as presented in Figure 3. Therefore, the regression equation and R^2 value indicated that there was a strong negative relationship between the percentage of *L.camara* and evenness of plant species.

Figure 3

*Relationship between percentage of *L.camara* and evenness of plants per invaded quadrat ($R^2 = 0.8662, p < 0.01$)*



3.4. Impact of *Lantana camara* invasion on the floristic composition

The *L.camara* invasion heavily damaged the composition and structure of invaded floral communities in the study areas. In this study, floristic composition between *L.camara* invaded and non-invaded areas was compared. A total of 125 plant species belonging to 49 families of plants were collected during the current study. The number of plant families was 44 in the non-invaded area in contrast to only 30 in the *L.camara* invaded areas. The number of family decreased by 31.82% in the *L.camara* invaded area as compared to the non-invaded. In invaded areas, of the 30 plant families, Fabaceae accounts the highest (14.29%), followed by Euphorbiaceae (8.93 %), and Malvaceae and Myrsinaceae accounts 7.14% each holding the

third place among the plant species recorded in the *L.camara* invaded study areas as indicated in Table 7. These four families contributed 37.5% of species to the total flora in *L.camara* invaded study sites.

Table 7

Number of plant species within the total families' in the invaded study sites

No.	Families	Number of species in the given family
1	Amaranthaceae	1
2	Asparagaceae	2
3	Acanthaceae	3
4	Agavaceae	1
5	Aloaceae	1
6	Apocynaceae	1
7	Astraceae	1
8	Balanitaceae	1
9	Capparaceae	1
10	Celastraceae	1
11	Combretaceae	2
12	Cucurbitaceae	1
13	Euphorbiaceae	5
14	Fabaceae	8
15	Lamiaceae	1
16	Malvaceae	4
17	Melanthaceae	1
18	Menispermaceae	1
19	Moraceae	1
20	Myrsinaceae	4
21	Myrtaceae	1
22	Oleaceae	2
23	Poaceae	2
24	Rhamnaceae	1
25	Rubiaceae	2
26	Santalaceae	1
27	Solanaceae	2
28	Tiliaceae	1
29	Ulmaceae	2
30	Verbenaceae	1
Total number of species		56

In non-invaded areas, of the 44 plant families, Fabaceae accounts the highest (15.61%), followed by Asteraceae (10.12%), Malvaceae (5.51%) in the third place, and Euphorbiaceae

and Celastraceae (4.59%) each holding the fourth place among the plant species recorded in the non-invaded study areas as shown in Table 8. These five families contributed 40.42% of species to the total flora in non-invaded study sites.

Table 8

Number of plant species within the total families' in the study site (in the non- invaded areas)

No.	Family	Number of species in the given family
1	Acanthaceae	4
2	Agavaceae	1
3	Aloaceae	1
4	Amaranthaceae	2
5	Anacardiaceae	2
6	Apocynaceae	2
7	Araceae	1
8	Asteraceae	11
9	Balanitaceae	1
10	Bignoniaceae	1
11	Boraginaceae	2
12	Capparidaceae	1
13	Capparisdaceae	2
14	Celastraceae	5
15	Combretaceae	3
16	Convolvulaceae	2
17	Crassulaceae	1
18	Cucurbitaceae	1
19	Euphorbiaceae	5
20	Fabaceae	17
21	Guttiferae	1
22	Lamiaceae	4
23	Malvaceae	6
24	Menispermaceae	2
25	Moraceae	1
26	Myrsinaceae	2
27	Myrtaceae	2
28	Papaveraceae	1
29	Poaceae	1
30	Polygonaceae	2

No.	Family	Number of species in the given family
31	Proteaceae	1
32	Ranunculaceae	2
33	Rhamnaceae	3
34	Rosaceae	2
35	Rutaceae	2
36	Santalaceae	1
37	Sapindaceae	1
38	Scrophulariaceae	1
39	Solanaceae	2
40	Sterculiaceae	1
41	Tiliaceae	1
42	Ulmaceae	2
43	Verbenaceae	1
44	Vitaceae	2
Total number of plant species within those families		109

Among the 125 plant species identified during the study, 38 species were found common in non-invaded and invaded areas as indicated in Table 9. *L.camara* was found to be the most dominant plant species in invaded study sites followed by *Solanum incanum*, *Achyranthes aspera* and *Parthenium hysterophorus*, respectively. Majority of the plants identified (78.4%) during this study were trees and shrubs. In invaded and non- invaded areas 44% and 34.4% were shrubs and trees, respectively.

Table 9

Floristic composition of the vegetation in the non-invaded and L.camara invaded study areas

No.	Scientific name	Family	Non-invaded	Invaded
1	<i>Acacia abyssinica.</i>	Fabaceae		
2	<i>Acacia oerfota.</i>	Fabaceae		X
3	<i>Acacia.bussei.</i>	Fabaceae		X
4	<i>Acacia saligna</i>	Fabaceae		X
5	<i>Acacia Senegal</i>	Fabaceae		X
6	<i>Acacia seyal</i>	Fabaceae		X
7	<i>Acacia Spp.</i>	Fabaceae		X
8	<i>Acacia tortilis</i>	Fabaceae		
9	<i>Acanthus spp</i>	Acanthaceae		
10	<i>Achyranthes spp.</i>	Amaranthaceae		X
11	<i>Achyranthes aspera</i>	Amaranthaceae		
12	<i>Acokanthera schimperi</i>	Apocynaceae		

No.	Scientific name	Family	Non-invaded	Invaded
13	<i>Agave sisalana</i>	Agavaceae		
14	<i>Ageratum conyzoides</i>	Asteraceae		X
15	<i>Ajuga Spp.</i>	Lamiaceae		X
16	<i>Aloe Spp.</i>	Aloaceae		
17	<i>Amaranthus caudatus.</i>	Amaranthaceae		X
18	<i>Argemone ochroleuca</i>	Papaveraceae		X
19	<i>Asparagus officinalis</i>	Asparagaceae	X	
20	<i>Asperagus aspera</i>	Asparagaceae	X	
21	<i>Aspilia africana</i>	Astraceae		X
22	<i>Balanites aegyptiaca</i>	Balanitaceae		
23	<i>Bersama abyssinica</i>	Melanthaceae	X	
24	<i>Cadaba farinose</i>	Capparidaceae		X
25	<i>Caesalpinia decapetala</i>	Fabaceae		
26	<i>Calpurnia aurea</i>	Fabaceae		
27	<i>Capparis spinosa</i>	Capparidaceae		X
28	<i>Capparis tomentosa</i>	Capparaceae		
29	<i>Carissa edulis</i>	Apocynaceae		X
30	<i>Celtis africana</i>	Ulmaceae		
31	<i>Celtis gomphophylla</i>	Ulmaceae		
32	<i>Cirsium spp.</i>	Asteraceae		X
33	<i>Cissampelos mucronata</i>	Menispermaceae	X	
34	<i>Cissus aphylla</i>	Vitaceae		X
35	<i>Cissus.cactiformis</i>	Vitaceae		X
36	<i>Clausena.anisata</i>	Rutaceae		X
37	<i>Clematis.hirsute</i>	Ranunculaceae		X
38	<i>Clematis.longicauda</i>	Ranunculaceae		X
39	<i>Clutia.abysinica.</i>	Euphorbiaceae		
40	<i>Colocasia esculenta.</i>	Araceae		X
41	<i>Combretum collinum</i>	Combretaceae	X	
42	<i>Combretum molle</i>	Combretaceae		
43	<i>Commelina benghalensis</i>	Commelinaceae		X
44	<i>Cordia africana</i>	Boraginaceae		X
45	<i>Cordia monoica</i>	Boraginaceae		X
46	<i>Croton macrostachyus.</i>	Euphorbiaceae		
47	<i>Cucumis ficifolius</i>	Cucurbitaceae		X
48	<i>Cynodon dactylon</i>	Poaceae		X
49	<i>Datura stramonium</i>	Solanaceae		X
50	<i>Desmodium repandum</i>	Fabaceae		X
51	<i>Dichrostachys cinrea</i>	Fabaceae		
52	<i>Dicliptera maculate</i>	Acanthaceae		
53	<i>Dodonaea angustifolia</i>	Sapindaceae		X
54	<i>Dombeya torrida</i>	Sterculiaceae		X
55	<i>Embelia schimperi</i>	Myrsinaceae	X	
56	<i>Erythrina brucei</i>	Fabaceae		X
57	<i>Eucalyptus camaldulensis</i>	Myrsinaceae		
58	<i>Euphorbia abyssinica</i>	Euphorbiaceae		
59	<i>Euphorbia pulcherrima</i>	Euphorbiaceae	X	
60	<i>Euphorbia tirucalli</i>	Euphorbiaceae		

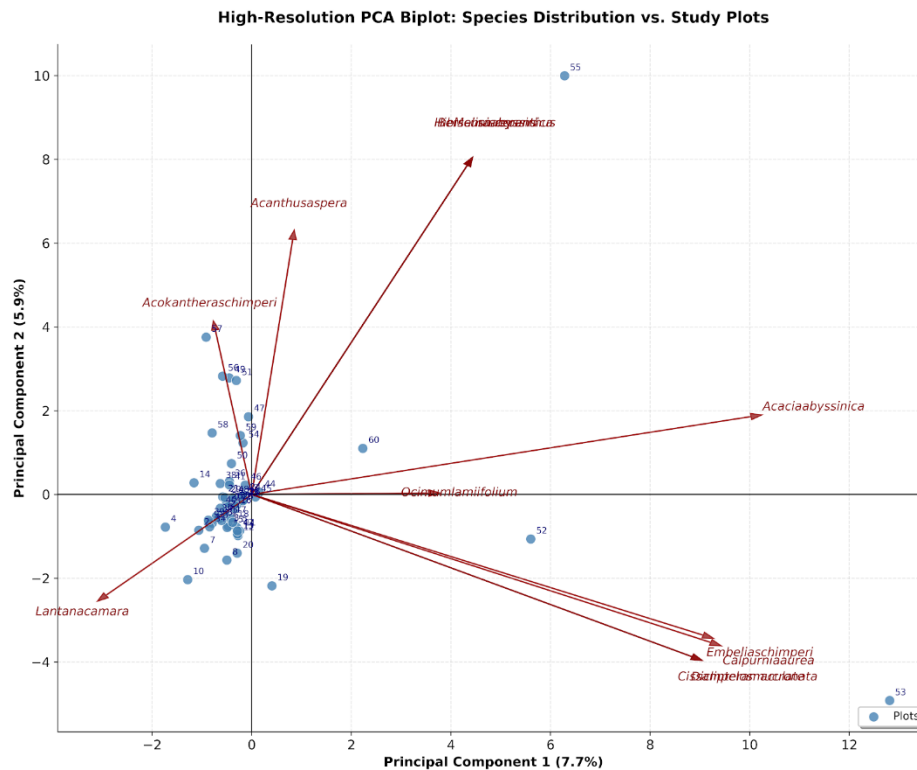
No.	Scientific name	Family	Non-invaded	Invaded
62	<i>Ficus thonningii</i>	Moraceae	X	
63	<i>Ficus vasta</i>	Moraceae		X
64	<i>Galiniera saxifrage</i>	Rubiaceae	X	
65	<i>Gardenia ternifolia</i>	Rubiaceae	X	
66	<i>Gravilla robusta.</i>	Proteaceae		X
67	<i>Grewia bicolor</i>	Tiliaceae		
68	<i>Hibiscus acetosella.</i>	Malvaceae		X
69	<i>Hibiscus aethiopicus</i>	Malvaceae		X
70	<i>Hibiscus.macranthus</i>	Malvaceae	X	
71	<i>Hibiscus Spp.</i>	Malvaceae		X
72	<i>Hippocratea africana</i>	Celastraceae		X
73	<i>Hypericum quartinianum</i>	Guttiferae		X
74	<i>Hypoestes forskoolii</i>	Acanthaceae	X	
75	<i>Ipomoea batatas</i>	Convolvulaceae		X
76	<i>Ipomoea purpurea</i>	Convolvulaceae		X
77	<i>Jacaranda Memosifolia</i>	Bignoniaceae		X
78	<i>Kalanchoe petitiana</i>	Crassulaceae		X
79	<i>Lantana camara</i>	Verbenaceae		
80	<i>Maesa lanceolata</i>	Myrsinaceae		
81	<i>Maytenus addat</i>	Celastraceae		X
82	<i>Maytenus arbutifolia</i>	Celastraceae		
83	<i>Maytenus spp</i>	Celastraceae		X
84	<i>Melinis repens</i>	Poaceae	X	
85	<i>Microglossa pyrifolia</i>	Asteraceae		
86	<i>Momordica foetida</i>	Cucurbitaceae	X	
87	<i>Myrsine africana</i>	Myrsinaceae		
88	<i>Mytenus africana.</i>	Celastraceae		X
89	<i>Ocimum lamiifolium</i>	Lamiaceae		
90	<i>Ocimum spp.</i>	Lamiaceae		X
91	<i>Olea spp</i>	Oleaceae	X	
92	<i>Osyris quadripartita</i>	Santalaceae		
93	<i>Parthenium hysterophorus</i>	Astraceae		
94	<i>Prunus africana</i>	Rosaceae		X
95	<i>Psidium guajava</i>	Myrtaceae		X
96	<i>Rhus natalensis</i>	Anacardiaceae		X
97	<i>Rhus vulgaris</i>	Anacardiaceae		X
98	<i>Ricinus communis</i>	Euphorbiaceae		X
99	<i>Roza abyssinica.</i>	Rosaceae		X
100	<i>Rumex abyssinicus</i>	Polygonaceae		X
101	<i>Rumex.nervosus.</i>	Polygonaceae		X
102	<i>Schrebera alata.</i>	Oleaceae	X	
103	<i>Senna didymobotrya</i>	Fabaceae		
104	<i>Senna occidentalis.</i>	Fabaceae		
105	<i>Senna Spp.</i>	Fabaceae		X
106	<i>Senra incana</i>	Malvaceae		
107	<i>Sida rhombifolia</i>	Malvaceae		
108	<i>Sida schimperiana</i>	Malvaceae		
109	<i>Solanum incanum</i>	Solanaceae		

No.	Scientific name	Family	Non-invaded	Invaded
110	<i>Stephania abyssinica</i>	Menispermaceae		X
111	<i>Syzygium guineense</i>	Myrtaceae		
112	<i>Teclea nobilis</i>	Rutaceae		X
113	<i>Terminalia laxiflora</i>	Combretaceae		X
114	<i>Trigonella Spp.</i>	Fabaceae		
115	<i>Verbascum sinaiticum</i>	Scrophulariaceae		X
116	<i>Vernonia Spp.</i>	Asteraceae		X
117	<i>Vernonia amalgadina.</i>	Asteraceae		X
118.	<i>Vernonia auriculifera</i>	Asteraceae		X
119	<i>Vernonia schimperi.</i>	Asteraceae		X
120	<i>Withania somnifera</i>	Solanaceae	X	
121	<i>Xanthium spinosum</i>	Asteraceae		X
122	<i>Xanthium strumarium</i>	Asteraceae		X
123	<i>Ziziphus abyssinica</i>	Rhamnaceae		X
124	<i>Ziziphus spina.christi.</i>	Rhamnaceae		
125	<i>Zizipus Spp.</i>	Rhamnaceae		X

3.5. Ordination analysis of *Lantana camara* - invaded plant communities

Figure 4

Principal Components Analysis ordination diagram of the plots and plant species for invaded floral communities



Principal Component Analysis (PCA) indicated the interrelationships between the study plots and abundance of plant species in *L. camara* -invaded plant communities. The result

of the study showed most of the plant species (73.21%) spread along the PCA biplot axis. In contrast, the PCA revealed the segregation of dominant IAPSs such as *Parthenium hysterophorus* showing its overall dominance in the study areas next to *L.camara* as shown in Figure 4. Moreover, the PCA biplot axis, indicated the segregation of some indigenous plant species including *Grewia bicolor*, *Achyranthes aspera*, *Calpurnia aurea*, *Embelia schimperi*, *Acacia abyssinica*, *Balanites aegyptiaca*, *Acokanthera schimperi*, *Maytenus arbutifolia*, *Ocimum lamiifolium* and *Hypoestes forskolii*. In addition, in the invaded floral communities, majority of the plots were close together. Conversely, plots 52, 53 and 55 were far apart to each other's and from the other plots.

4. Discussion

4.1. General Impacts of *L.camara*

The study indicated that *L.camara* severely impacts the diversity and composition of invaded floral communities. Consistent with Barahukwa *et al.* (2023), tree density was significantly lower in areas currently or previously occupied by *L.camara*. These results also reinforce the status of *L.camara* as one of the world's most damaging bio-invaders. It is consistently ranked among the "100 World's Worst Invasive Alien Species" because of its high plasticity and its ability to escape cultivation to exert deleterious effects on plants, animals, and soil microorganisms (Barik *et al.*, 2020; Gioria *et al.*, 2023). The alteration of plant community composition documented likely has cascading effects on higher trophic levels, affecting both habitat quality for wildlife and the availability of ecosystem services for local communities.

This suppression is attributed to *L.camara* limiting seedling recruitment by outcompeting native flora for light, nutrients, and space (Barahukwa *et al.*, 2023; Kar *et al.*, 2014). Beyond physical competition, the plant utilizes allelopathic interference, releasing phenolics and secondary metabolites that inhibit the germination and root elongation of neighboring species. While not directly tested in this study, extensive literature suggests that *L.camara* releases phenolics and other secondary metabolites into the soil, which can inhibit the germination and root elongation of neighboring plant species (Kar *et al.*, 2014; Banerjee & Sati, 2026). This biochemical advantage, coupled with a dense canopy, establishes an "exclusion zone" that prevents the establishment of native climax species. Consequently, the

presence of *L.camara* alters the successional trajectory of the ecosystem, leading to reduced species richness and long-term ecological degradation.

The results further indicated that the impact of *L.camara* is not uniform across all growth forms. The herbaceous layer and native shrubs experienced the most significant declines in diversity compared to mature trees. The effect is most severe in the lower strata; herbs and grasses are eliminated via dense shading and allelopathy (Barik *et al.*, 2020). This is consistent with findings by Gebrewahid *et al.* (2025), which suggest that the "shading effect" of *L.camara* thickets is most detrimental to light-demanding annuals and understory plants. It is exerting a stratified impact on ecosystem architecture. Native shrubs are displaced through intense niche competition, often resulting in *L.camara* monocultures (Ntalo *et al.*, 2022). While mature trees survive initially, the species creates a "demographic bottleneck" by suppressing seedling recruitment (Banerjee & Sati, 2026). This halts natural succession, ensuring the invader eventually replaces the native canopy, leading to total ecosystem collapse and a shift in community structure (Gioria *et al.*, 2023).

L.camara has become the dominant under story species, encroaching agricultural land, reducing the carrying capacity of the pastures, disrupting succession and decreasing biodiversity. Not only in natural forests but also in protected areas, its invasion is considered a major threat to native plants diversity. It is a major threat to the ecosystem, including plants and animals (Pathak *et al.*, 2021). Its impact on agriculture, forestry and native biodiversity is marked because of the species' invasive characteristics, such as rapid vegetative growth, aggressive competitive ability, fire tolerance, high seed production, high percentage fruit set and proliferation throughout the year in ideal environmental conditions. There are allelochemicals present in all parts of the plant (Kar *et al.*, 2014). Particularly, its leaves, roots and fruits contain allelochemicals mainly aromatic alkaloids and phenolics (Sharma *et al.*, 2005; Banerjee & Sati, 2026).

4.2. Impact of *L.camara* on diversity of plant species

The result of this study indicated that the plant species richness and evenness, Margalef index of richness, Simpson(1-D) and Shannon(H') indices of diversities were reduced significantly in the *L.camara* invaded areas as compared to non-invaded. There were variations in the plant species richness across various infestation levels of *L.camara* based on the outcome of a one-way ANOVA. In line with the findings, the results of the study by Ruwanza (2020)

indicated that all indices of diversity, specifically Shannon-Wiener index, species richness, and evenness varied substantially amongst the different invasion status of *L.camara*. One-way ANOVA, regression and ordination analyses also showed a strong negative relationship between the coverage of *L.camara* and diversity of plant species. It indicated that there was a justification for the existence of great impact of *L.camara* on diversity of plant species. In agreement with the findings, the outcome of the investigation by Ruwanza (2020) confirmed that species richness for both alien and native species decreased with increasing *L.camara* relative cover in both the *L.camara* high and low invasion condition.

The results of the study indicated that plant species richness, evenness, Simpson(1-D) and Shannon(H') indices of diversity were reduced by 48.6%, 57%, 66.04% and 74.48%, respectively in the *L.camara* invaded areas as compared to non-invaded areas. In line with the finding, the study of Paudel *et al.* (2024) indicated that in invaded sites, *L.camara* reduced the species richness, Simpson and Shannon diversity indices by 36.84%, 11.84%, and 40.21%, respectively. The report of the study by Sharma *et al.* (2005), French *et al.* (2009) and Barik *et al.* (2020) indicated that the impacts of *L.camara* on native biodiversity is highly marked. In agreement with the finding, the report of the study by Raphela and Duffy (2023) confirmed that the presence of *L.camara* negatively affected species abundance, richness, and diversity of large and small mammals, as well as how these species were distributed across the invaded and cleared areas.

In line with the finding of the investigation, the study by Bekele (2018) and Zhang *et al.* (2021) also indicated the different impacts of *L.camara* on the diversity of plants species and other socioeconomic impacts. In agreement with the finding, the result of study by Chaudhari *et al.* (2021) and Kacheche and Mzuza (2021) also confirmed that IAPSs had significant impact on the species richness, evenness and composition of invaded floral communities. As the percentage of *L.camara* increased, species evenness per study site decreased. Evenness (E) has values between 0 and 1.0, where 1.0 represents a situation in which all species are equally abundant (Oulu, 2016).

The dramatic decline in species richness observed in this study suggests that *L.camara* acts as a "biotic filter," selectively eliminating native flora through a synergistic combination of resource pre-emption and allelopathy. Beyond simple physical crowding, the dense thickets create a "biotic shadow" that drives light levels below the compensation point for heliophilic herbs, while the release of phenolic compounds disrupts the germination of the native seed

bank (Mishra & Tripathi, 2021). Although the regression analysis yielded a low R^2 value, this is the characteristic of complex ecological systems where richness is co-governed by stochastic factors such as micro-topography and historical seed bank dynamics. Rather than indicating a weak relationship, this "noise" underscores that *L.camara* is a primary driver of a "demographic bottleneck," where the interruption of seedling recruitment prevents natural forest succession and catalyzes a transition toward biotic homogenization (Gioria *et al.*, 2023).

4.3. Impact of *L.camara* Invasion on the Floristic Composition

In line with the finding, the study by Hansda *et al.* (2024) confirmed that *L.camara* are posing a serious risk to plant composition in forest environments. Its capacity to spread speedily and contend violently with native flora has caused profound ecological disproportions, leading to habitat loss for various species and modification of ecosystem processes. In agreement with the finding, the study by Vardien *et al.* (2012) indicated that the floristic composition and number of family decreased significantly in the *L.camara* invaded area. The most dominant family in *L.camara* invaded plant community of the study area was Fabaceae. This might be due to, the successful dispersal mechanisms and an ability to fix atmospheric nitrogen as well as remarkably successful pollination system which may serve to explain why Fabaceae among the world's leading invaders. Progressive features that might be considered Fabaceae as an evidence for effective invasion are: high reproductive rate, lengthy viability of seeds or C4 photosynthetic pathways (Cronquist, 1981; Stešević & Petrović, 2010).

The PCA, which was based on species abundance, indicated that most of the *L.camara* invaded plots grouped closely together, hence being very similar in species composition (Paliy & Shankar, 2016). Such clustering may imply that heavy invasion generates a "biotic homogenization" effect, whereby diverse native communities become reduced to a common pool of resilient species (Chahouki, 2012). Even though environmental variables have not been directly measured, the closeness of such sites within ordination space would probably mean that they share a typical "invasion-mediated environment." What this means is that, with the increase in the density of *L.camara*, it overrides the local site-specific variations, such as soil micro-topography, and then imposes a standardized ecological state. Therefore, the distance observed between the invaded and uninvaded sites reflects a deep shift in the floristic composition, where the presence of the invader becomes the major determinant of community

structure and masks the previous environmental heterogeneity of the landscape accordingly (Oulu, 2016).

Conversely, plots 52, 53 and 55 were far apart to each other and from the other plots, which might indicate that those plots were dissimilar in species composition. Moreover, the PCA graph also indicated the segregation of IAPSs such as *Parthenium hysterophorus* and indigenous plant species including *Grewia bicolor*, *Achyranthes aspera*, *Calpurnia aurea*, *Embelia schimperi*, *Acacia abyssinica*, *Balanites aegyptiaca*, *Acokanthera schimperi*, *Maytenus arbutifolia*, *Ocimum lamiifolium* and *Hypoestes forskaolii*, showing their general dominance in the study sites next to *L.camara*. This is due to the resistant of these IAPSs and indigenous plant species against the invasions of *L.camara*.

5. Conclusion

L.camara is categorized as the dominant IAPS in the selected study kebeles of the Mirab Abaya, Dilla Zuria, and Dara districts, Ethiopia, where it has reduced species diversity and altered the composition of invaded plant communities. It is one of the highest-impact IAPSs in the study area. Therefore, an integrated management approach combining mechanical removal, targeted chemical control, and the evaluation of biological control options is recommended. Moreover, the districts should initiate community-based eradication campaigns against *L.camara* during the pre-flowering season to deplete the seed bank. Furthermore, the cleared biomass should be economically valorized to create financial incentives that ensure long-term community participation in the management process. Effective coordination among administrative levels, along with further research, is essential to develop sustainable and site-specific control strategies.

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