Analyzing The Effect of "Lantana Amara" Invasion on Density, Frequency, Dominance, And Important Value Index of Woody Species in The Lake Tana Sub Basin

Tesfaye Bayu[12] , Tri Retnaningsih Soeprobowati[23], Solomon Adissu[4], Budi Warsito[25]

[1] *Debre Markos University, Burie campus P.O. Box 18 Burie, Ethiopia, phone 0910611253 email tesfayebayu235@gmail.com*
[2] *School of Postgraduate Studies, Universitas Diponegoro, Semarang, Indonesia, email: trsoeprobowati@live.undip.ac.id*
[3]*Department of Biology, Faculty of Science and Mathematics Universitas Diponegoro, Semarang, Indonesia*
[4] *Bahir Dar University, collage of agriculture and environmental science, Ethiopia Email: soladd2000@yahoo.com*
[5]*Department of statistics, Faculty of Science and Mathematics Universitas Diponegoro, Semarang, Indonesia Email: budiwarsitoundip@gmail.com*

Abstract. Invasive plant species can disrupt recovery pathways by altering species interactions and ecosystem structure and functioning. The species compositional changes induced by Lantana invasion are primarily driven by gradual changes in species density. This research tries to analyze the effect of *Lantana camara* invasion of density, dominance, important value index, species richness, and evenness in the Lake Tana subbasin. The finding revealed that species dominance (48.36) in the not invaded area is higher than invaded area (121.07). The total number of species recode in invaded (2031) area was lower than in the uninvaded area (5085). The uninvaded area (3.73) is richer in terms of species composition than invaded area (2.84). The invasive species *Lantana camara* affects the density, frequency, and important value index of other species by suppressing their composition. It also affects the species distribution by affecting species evenness and richness of the study area. The invasive species affect biodiversity composition and ecosystem services in the Lake Tana sub-basin. Comprehensive management strategies should be designed by the government, policymakers, and environmentalists to minimize the effect of *Lantana camara* invasion on biodiversity composition.

Keywords; Invasive spices, Invaded area, *Lantana camara*, Species distribution

*Corresponding author: tesfayebayu235@gmail.com

1 INTRODUCTION

As it produces habitats and resources that support a wide range of other organisms and serve as the cornerstone of particular ecosystems, the diversity of woody species is essential to maintaining forest biodiversity (Deák et al., 2020). In order to protect soil, cycle nitrogen, control water flow and microclimate, promote agricultural and animal productivity, and provide food security, woody forests play a critical role in offering a variety of ecosystem services (Birhanu et al., 2021). It is essential to develop management and conservation strategies for forest resources that are economically viable, socially acceptable, and ecologically sustainable considering the cost incurred by invasive species (Mebrat, 2015).

The changes in species composition observed in response to the invasion of Lantana are primarily driven by the alterations in species density (Gooden et al., 2009). These changes in density distribution of trees, shrubs, and herbs provide valuable insights into the future structure of woodland forests (Hagmann et al., 2021). To determine invasive plant species and their effects on the ecology and biodiversity in Ethiopia, several research investigations have been carried out (Shiferaw et al., 2018). The density, frequency, dominance, and Important Value Index of Lantana in the woodland forest of the Lake Tana sub-basin, however, have not been specifically addressed in any studies. It is essential to comprehend the community structure in this region in order to create cutting-edge invasive species management strategies that can protect ecosystem services and biodiversity (Rawat et al., 2023).

A significant portion of the sub-basin area is currently unable to provide goods and services to the local community due to *Lantana camara* invasion (Bezabih et al., 2021). Unfortunately, information regarding the invasion rate, density, and population dynamics of Lantana camara in this specific area is lacking. This information is essential for designing effective management strategies that can minimize the negative impact of invasive species on the livelihoods of the local community. The objective of the research paper is to analyze the density, frequency, dominance, and important value index of the invasive plant species Lantana camara in the Lake Tana sub-basin. Specifically, the study aims to analyze the density, frequency, dominance, and importance value index of Lantana camara as an invasive species and conduct species richness and evenness analysis in the study area.

2 METHODOLOGY

2.1 Description Of Study Area

The research site is situated in the Amhara National Regional State, specifically in the Lake Tana Sub-basin (LTSB) of the Blue Nile Basin. The Blue Nile Basin is recognized as the largest river basin in Ethiopia and comprises the LTSB, home to the world's largest freshwater and oligotrophic-high altitude lake, Lake Tana (CSA, 2012). The area cover a total land area of 1,589,654.98 hectares in the upper reaches of the Blue Nile River (CSA 2012). The atmospheric temperature at Lake Tana sub basin typically falls between 13 and 22 °C, with a decrease of 0.7 °C per 100 m in elevation (Goshu & Aynalem, 2017). Located geographically in the range of 10°45054.1" N, 36°10024.9" E and 12°50015.9" N, 38°50054.48" E (Dersseh et al., 2019), Lake Tana experiences an average annual rainfall of 1248 mm per year (mm yr−1). This represents a 7% reduction in rainfall when compared to the surrounding watershed. The Lake Tana basin is mainly characterized by cultivable land, which accounts for 71% of the area, followed by grazing land (9%), infrastructure (6%), forestland (3%), and other types of land. The major land cover types include farmland, water bodies, wetlands, forests, woodlands, shrubs, rangeland, grassland, and settlements. The dominant soil types on Lake Tana's islands, peninsulas, wetlands, and upland areas are Nitosols, Luvisols, and Vertisols(Goshu & Aynalem, 2017).

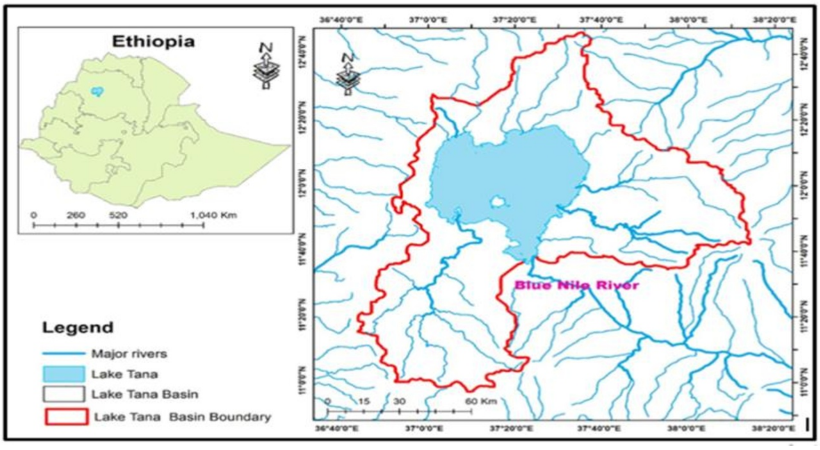

Figure 1. Map of the study area

2.2 Site Selection And Establishment Of Quadrants

In order to gather an initial understanding of the site conditions and determine the appropriate sampling methods for collecting data on invasive species, a reconnaissance survey was conducted during the second week of August 2022 (Temesgen & Warkineh, 2020). This survey focused on the lake shore area affected by water hyacinth and different terrestrial land use areas invaded by lantana. The main purpose of the reconnaissance survey was to obtain comprehensive information about the study site and identify the most suitable sampling method to be used (Temesgen & Warkineh, 2020). To document the invasive species Lantana camara, a systematic approach was employed, following the Braun-Blanquet method (Temesgen & Warkineh, 2020). A total of 42 sampling plots, each measuring 20m x 20m, were established for this purpose. Within each sampling plot, additional subplots were created to collect data on seedlings and saplings (ground flora) analysis. Specifically, five subplots were established in each sampling plot: two at each corner and one at the center. Each of these subplots measured 5m x 5m ($25m^2$). The number of quadrats placed along the transect line was determined by the length or size of the land under study. In total, 210 subplots were used to collect the necessary data in order to address the research question.

2.3 Data Collection And Identification.

Using a purposive sample strategy, study locations were chosen. Five *kebeles* (administrative subdivisions) where Lantana and water hyacinth affected agricultural operations were chosen, and five more *kebeles* close to the lake were chosen to build line transects based on sites found during the reconnaissance study. The dispersion and variability of the invasive alien plant species influenced the choice of these *kebeles*. A systematic sampling strategy was used to gather information on the dominance, relative frequency, density, and important value index of the invasive plant species (Hennink & Kaiser, 2022). Plotting had to be done along the line transects at regular intervals. Additionally, information about the number and kinds of species found in each quadrant was logged during the study.

2.4 Data Analysis Method.

Frequency (F): $= \frac{Number\ of\ plots\ in\ which\ lantana\ species\ occur}{Total\ number\ of\ plots\ layout\ in\ the\ study\ site} \times 100$ ---------- equation (1)

Species were grouped into five frequency classes: A =>81; B = 61-80.9%; C = 41-60.9%; D = 21-40.9%; E = <=20.9%.

Relative Frequency **(RF)** = $\frac{Frequency\ of\ lantana\ species}{Frequency\ of\ all\ tree\ species} \times 100$ ------------------- equation (2)

Density (D) = $\frac{Number\ of\ above\ ground\ stems\ of\ lantana\ species\ countered}{Sampled\ area\ in\ hectare\ (ha)}$ ------------- equation (3)

The density of a given species is expressed as a number of stems per hectare. Species were classified into five density classes, A - E as follows: A > 100.1; B = 50.1-100; C = 10.1-50; D = 1.1-10 and E < 1.

RD = $\frac{Number\ of\ Individuals\ of\ lantana\ species}{Total\ Number\ of\ Individuals\ )}$X100 ------------------- equation (4)

Abundance = $\frac{Total\ number\ of\ individuals\ of\ lantana\ species\ in\ all\ quadrates}{Total\ number\ of\ quadrates\ in\ which\ the\ species\ occurred}$ ----------- equation (5)

Special distribution (%) = $\frac{Abandance\ of\ each\ species}{Ferquancey\ of\ each\ species}$ ------------------- equation (6)

The distribution of the trees and shrubs is said to be regular, random, and contagious when the value of distribution pattern is < 0.025, 0.025- 0.05, and >0.05 respectively (Sahu et al., 2019).

$H' = \sum_{i=1}^{s} \quad Pi * ln * pi,$

where H′ represents the diversity of species, s represents the number of species, Pi represents the proportion of individuals abundance of the i[th] invasive species, and ln represents the natural log. Shannon diversity index considered as high when the calculated value is ≥3.0, medium when it is between 2.0 and 3.0, low between 1.0 and 2.0, and very low when it is ≤ 1.0 (Cavalcanti & Larrazábal, 2004).

$D = \sum_{i=1}^{s} \quad (pi)^2$------------------- equation (7)
Where D represents Simpson's dominance, s represents the number of species, and Pi represents the proportion of individual's abundance of the i[th] species
$E = \frac{H}{ln\ s}$------------------- equation (8)
Where E represents is the species evenness, H′ represents Shannon's index, and s represents the number of species. H and D were used to measure the dominance of invasive species in the study area.

3 RESULT AND DISCUSSION

3.1 Plant Species Composition, Richness, And Diversity

A total of 45 plant species belonging to 27 families were documented from the 42 uninvaded plots. Among these species, the dominant life form distribution was observed in shrubs, accounting for 57.78% of the recorded species, followed by herbs at 28.89% and trees at 13.33% (Figure 3). The most abundant families identified in the uninvaded plots were Fabaceae at 11.63%, Acanthaceae and Asteraceae at 9.3%, Rutaceae at 6.98%, and Euphorbiaceae at 4.65% (Reference needed). These five families collectively covered 37.21% of the uninvaded area in the study site. The remaining 62.79% of the uninvaded areas were covered by 22 other families (Table 5).

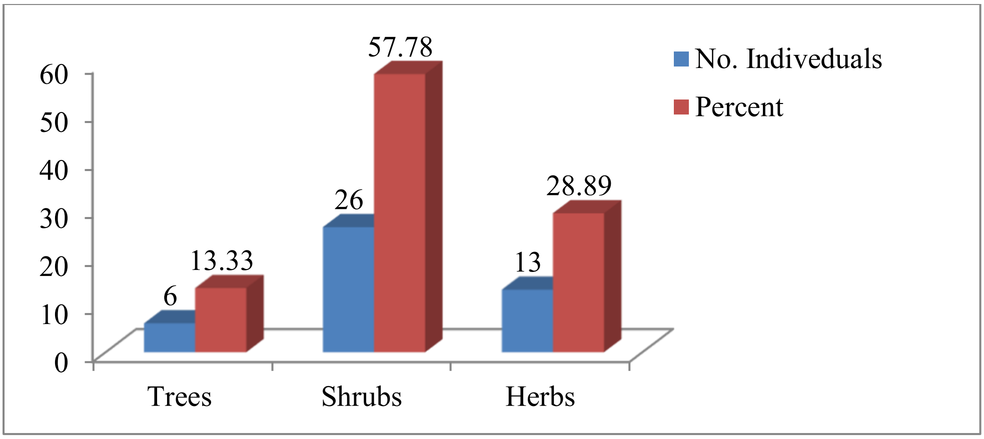

Figure 3. Plant species composition in the study area

From the 42 invaded plots, a total of 35 plant species belonging to 22 families were recorded (Reference needed). The life form distribution of these species was primarily dominated by shrubs, accounting for 62.5% of the recorded species, followed by herbs at 25% and trees at 12.5% (Figure 4). The most abundant families identified in the invaded plots were Fabaceae and Acanthaceae, each representing 12.5%, followed by Acanthaceae at 9.38%. Additionally, Rosaceae, Euphorbiaceae, and Thymelaeaceae each constituted 6.25% of the invaded area (Reference needed). These six families collectively covered 53.13% of the invaded area in the study site. The remaining 46.87% of the invaded areas were covered by 15 other families (Table 4).

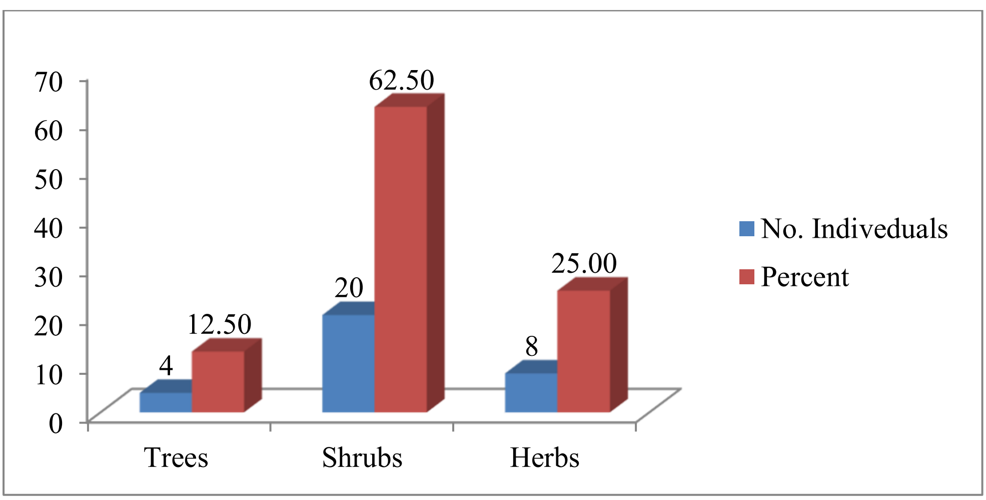

Figure 4. Species composition of invaded area in the sub basin

3.2 Frequency, Density, And Distribution Pattern Of The Plant Species

Both the invaded and uninvaded plots did not comply with the Raunkiaer rule of normal frequency distribution, according to the examination of frequency percentages (Malik et al., 2021). The bulk of the species in the invaded area belonged to class E, the lowest frequency class (Figure 5). The order of the species was A > B > C > D > E in both strata as the size of the frequency class grew. For the uninvaded plots, there were specifically five species in frequency class C and three species in frequency class D (Figure 5).

Conversely, only two species were recorded in frequency class A for the invaded plots (Figure 5). Regarding the invaded plots, the species that exhibited the highest frequencies were *Lantana chamara* at 90.48%, followed by *Croton macrostachyus Del* at 85.71% and *Croton Justicia diclipteroides Lindau* at 80.95% (Table 2). On the other hand, for the uninvaded plots, the top three most frequent species were *Phytolacca dodecandra L'Herit* at 90.48%, *Pterolobium stellatum (Forssk)* Brenan at 45.33%, and *Rumex nervosus Vahl* at 85.71% (Table 1).

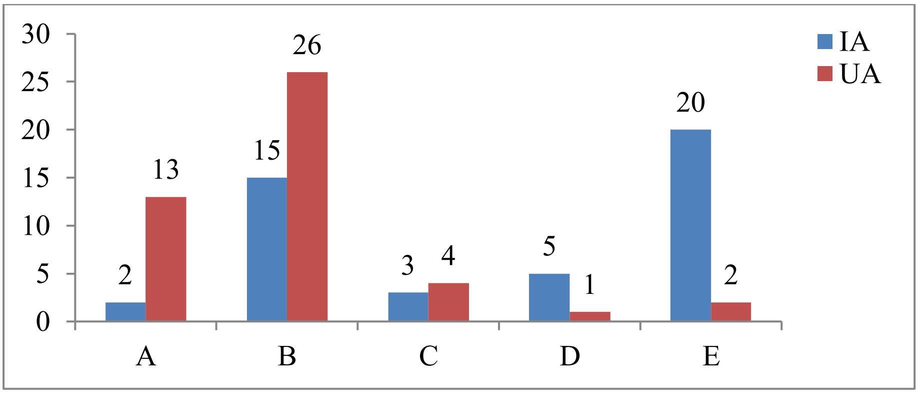

Figure 5. Frequency of species in invaded and univaded area

In general, the uninvaded plots exhibited higher densities for each type of plant species compared to the invaded plots (Figure 6) (Reference needed). In density class A, there were 28 species recorded in the invaded plots, while the uninvaded plots had 44 species. However, in density class B, only one species was observed in the uninvaded plots, whereas the invaded plots recorded six plant species. Density class C had eight species in the invaded plots, but none in the uninvaded plots (Figure 6). The three species with the highest densities in the invaded plots were *Lantana chamara* (2608), *Sida collina Schlechtend* (1400), and *Gnidia glauca (Fresen.) Gilg* (1283), as indicated in Table 2 (Reference needed). In contrast, the top three species with the highest densities in the uninvaded plots were *Pterolobium stellatum (Forssk) Brenan* (1408.33), *Sida collina Schlechtend* (1400), and *Dodonaea viscosa* (1300), as shown in Table 1.

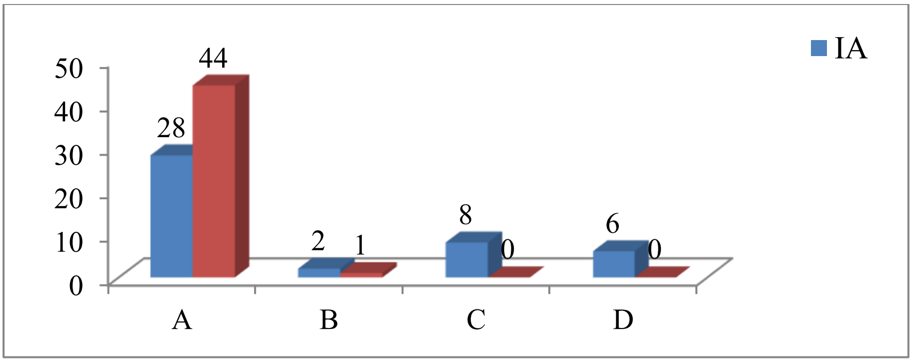

Figure 6. Density of species in invaded and uninvaded area

In the invaded plots, approximately 68.57% of the plant species exhibited a random distribution pattern, while 31.43% displayed a contagious distribution pattern, and no regular distribution pattern was observed (Figure 7). Similarly, in the uninvaded plots, around 68.57% of the plant species showed a random distribution pattern, 31.43% exhibited a contagious distribution pattern, and no regular distribution pattern was identified (Figure 7). Specifically, the expansive shrub Lantana camara displayed a random distribution in the invaded plots.

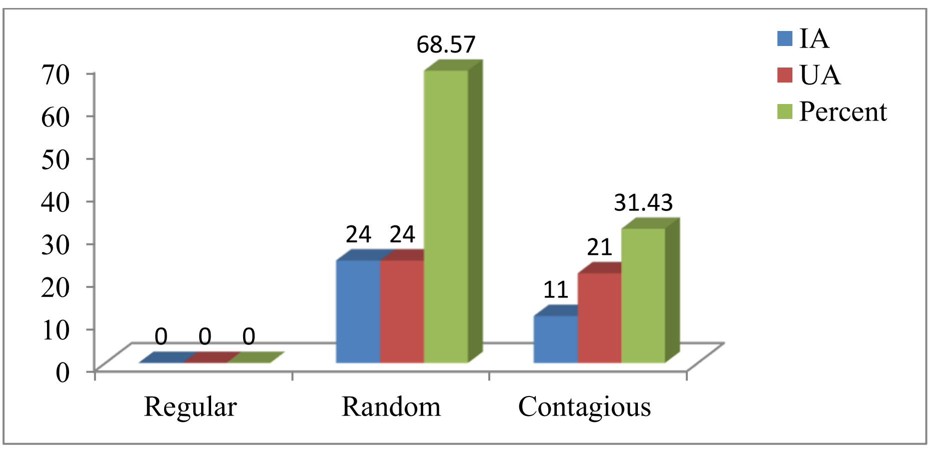

Figure 7. Species distribution for invaded and uninvaded area

3.3 Important Value Index

The IVI (Importance Value Index) values varied between 0.58 and 6.65 for the uninvaded plots and between 0.24 and 22.76 for the invaded plots (Table 1 and 2) (Reference needed). In terms of IVI values, the dominant species in the uninvaded plots were *Ficus sur Forss .K* (6.65), *Pterolobium stellatum (Forssk) Brenan* (6.04), and *Dodonaea viscosa* (5.83) (Table 1). On the other hand, the dominant species in the invaded plots were *Lantana camara* (22.76), *Sida collina Schlechtend* (14.07), and *Gnidia glauca (Fresen.) Gilg* (13.97) Table

3.4 Species Richness And Evenness

The Shannon-Wiener Diversity Index ('H') for the invaded plots was 3.73, while the Shannon-Wiener Diversity Index for the uninvaded plots was 2.84 (Table 3). For the invaded plots and the uninvaded plots, the Shannon-Wiener Diversity Index was assessed as moderate and high, respectively. In the invaded plots, *Lantana chamara*, *Sida collina Schlechtend*, and *Gnidia glauca (Fresen.) Gilg* were the top three species that significantly impacted the Shannon diversity index. The species *Sida collina Schlechtend*, *Pterolobium stellatum(Forssk)*, and *Ficus sur Forss K*, on the other hand, significantly increased the Shannon diversity index in the uninvaded plots.

According to Table 4, the uninvaded plots exhibited a higher species richness compared to the invaded plots. On average, the uninvaded plots had 121.07 species per plot, while the invaded plots had an average of 48.36 species per plot (Table 3). In terms of dominance, the Simpson index was 2.84 for the invaded plots and 3.73 for the uninvaded plots. Furthermore, there was a significant difference in evenness between the invaded plots (0.37) and the uninvaded plots (0.44). The Sorensen's similarity indexes for the plant species was 0.93, indicating that the invaded and uninvaded plots had a high similarity in terms of plant species composition (Reference needed). However, it is important to note that there was a slight decrease in similarity (0.97) when comparing the two plot types (Table 3).

Table 3. Species richness and evenness in the study area

	H	D	E	Total no. of species	Average no . of specie per plot
IA	2.84	0.93	0.37	2031	48.36
UA	3.73	0.97	0.44	5085	121.07

H (Shannon index), D (Simpson index) and E (Evenness index)

4 DISCUSSION

Lantana has been found to negatively impact the diversity and abundance of trees, shrubs, and herbs in woodland forests, inhibiting tree regrowth (Das et al., 2021). However, in cleared areas where lantana was absent, the nearby uninvaded woodland forests remained unaffected by its encroachment (Das et al., 2021). Surprisingly, even in Lantana-free sites, there was low recruitment of tree species (Barahukwa et al., 2023). This suggests that factors other than lantana may be influencing tree establishment in the study area. Tsirintanis et al. (2022)suggest that invasive species compete with native trees, shrubs, and herbs for light, nutrients, and space, thus impeding the establishment of native species. Although the severity of the effects differed between the two study locations, the abundance of invasive shrubs had a negative influence on plant composition, richness, and diversity in both invaded and uninvaded plots. This might be explained by the invasive bushes' high cover and aggressive character, which thrived in favorable environmental conditions and amid human disturbance. These results concur with those of (Haile et al., 2021), who noted a drop in plant species' structural traits (such as density, diameter, height, and basal area) as the invasive shrubs multiplied.

Species density was highest in uninvaded woody land areas, while areas previously and currently invaded by Lantana exhibited the lowest density. The limited density of small-size classes in invaded areas may be attributed to Lantana's competition for light, nutrients, and space, as well as its potential allelopathic effects, which hinder seedling recruitment (Shackleton et al., 2017). The decreased richness and diversity, along with increased evenness of sapling species observed in cleared and invaded sites, as supported by other studies (Ruwanza, 2020), could be attributed to the long-lasting allelopathic effects of Lantana at managed sites.

5 CONCLUSION AND POLICY IMPLICATION

The species composition, ecosystem services, and biodiversity composition are all significantly impacted by Lantana camara's presence. By looking at variables including frequency, density, important value index, species richness, and evenness in the chosen study area, this study seeks to determine the impact of Lantana camara on species composition. The results show that Lantana camara, an invasive species, significantly reduces biodiversity in the study area. Invaded areas show decreased species richness, evenness, and diversity when compared to uninvaded areas. Additionally, invasive species have a significant impact on the frequency, density, important value index, and species distribution, resulting in lower values when compared to areas that are not invaded.

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