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RESEARCH ARTICLE

Impacts and Status of Invasion by *Lantana Camara* in Natural Forests of an Indo-Burma Biodiversity Hotspot Region- A Case Study in Mizoram, India

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ABSTRACT

Invasion by *Lantana camara* represent a major threat for biodiversity and ecosystems functioning on a global scale. In this study, we investigated the ecological impact of *Lantana camara* invasion in natural forests of Mizoram. The sampling plots were implemented within six sites spread across the state and *Lantana camara* invasion were investigated along altitudinal gradient. In addition to the associated floristic inventory, we gathered the socio-economic utilization data. The results revealed that *Lantana camara* invasion cause adverse effects where it may result into suppression of various native plant species of invaded communities. The floristic and phytosociological assessment from *Lantana camara* invaded natural forests revealed a total of 74 species belonging to 68 genera and 30 families. Herbs were the dominant habit (60%) followed by shrubs (26.67%) and climbers (13.33%). The most dominant family was represented by Asteraceae with 18 species belonging to 16 genera. The general plant species diversity, density, richness and importance value index were reduced by the invasion of *Lantana camara*. Hence, based on the associated species present in the invaded study areas, forest management activities may be followed for the sustainable control measures to eliminate the spread of the invasive *Lantana camara*. This study recommends the imperative nature of effective *Lantana camara* management, particularly during the initial stages of invasion.

Keywords: Verbenaceae; Climate change; Plant invasion; Invasive alien plants; protected area; landscape ecology

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1. Introduction

Invasive plants are commonly recognized to have severe ecological impacts in a wide range of ecosystems throughout the world. They can alter ecosystem structure and function, trophic structure, resource availability and downgrade biodiversity of natural landscapes. *Lantana camara* is one such invasive alien species and considered by IUCN as one of the world's 100 most invasive species, and among the world's 10 worst weeds [1]. Invasion by non-native exotic plant species poses a serious threat to native plant communities and ecosystem properties, such as population dynamics and community structure [2], and alters native vegetation and causes threat to biodiversity [3].

The invasive alien plant, *Lantana camara* L., commonly known as wild or red sage, widespread and growing luxuriantly at elevations up to 1800 m asl. in tropical, sub-tropical and temperate regions [4]. However, as an introduced species they are found in various localities of the globe especially in the Australian-Pacific region (**Figure 1**). Dutch explorers introduced *Lantana* into the Netherlands from Brazil in the late 1600s and later explored from tropical, sub-tropical and temperate regions [5]. In the 18th and nineteenth century, nurserymen commercialized and popularized many colorful forms of *Lantana*, and it is now cultivated world-wide as an ornamental plant. The shrub *Lantana camara*, characterized by its compact stature, typically reaches heights ranging from 1.2 to 2.4 meters, leaves ovate-oblong, opposite phyllotaxy, exhibiting a rough texture and pubescent were introduced to India in 1809 [6]. This species subsequently spread to disrupt numerous forested, pasture, and fallow areas. *Lantana* has invaded most Indian pasture lands (13.2 million ha) besides forest and fallow areas causing expenses associated with its management are estimated at approximately US$ 70 per hectare [4]. These *Lantana* infested landscapes not only are impoverished as habitats of wildlife but also contribute to human-wildlife conflicts owing to diminished ecosystem services.

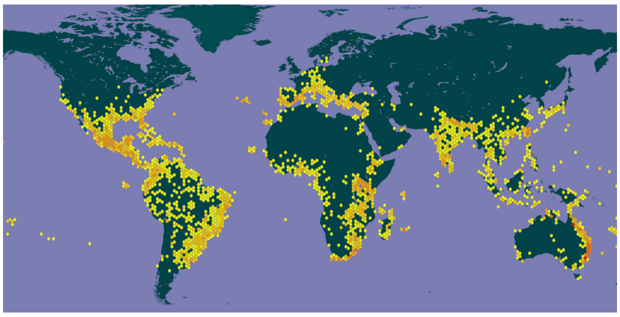

Figure 1. Worldwide distribution of *Lantana camara.*

Note: (latitudes & longitudes retrieved from GBIF); yellow hexagons – reported present occurrence co-ordinates; red hexagons- occurrence co-ordinates from herbarium records

Lantana occupies various habitats and soil types [7] dispersing through frugivores [8], anthropogenic activities [9], and forest fire [10]. Owing to the perennial reproduction and high regeneration potential, *L. camara* rapidly invades natural forests [11]. Several studies provide evidence indicating that once *L. camara* has established itself, eradication efforts prove largely futile [12], and hence early detection is the key to addressing invasion issues.

Despite the adoption of various management practices in India, both protected areas and non-protected ecosystems have faced significant invasion by *Lantana*. Its rampant spread has even extended into the temperate zones of the Indian Himalayan region, indicating a pressing need for widespread public awareness and effective management strategies. The present work aims to explore the present ecological impact of *L. camara* invasion in the natural forests of Mizoram along altitudinal gradient. Our study also discusses the different control methods utilized in *Lantana* management in the area, highlighting their sustainable socio-economy based uses for better control and management involving local livelihood generation.

This case study in Mizoram anticipates that the outcomes will help in developing a suitable management strategy for protected areas in Mizoram, which are presently threatened by the invasion of *Lantana camara* and other previously reported invasive alien plants like *Ageratina Adenophora*, *Mikania micrantha*, *Ageratum conyzoides* etc.

(Sengupta and Dash, 2020). Outcomes of this research will effectively address the primary research goal - identifying the ecological impact of *Lantana camara* in Mizoram, a part of Indo-Bura biodiversity hotspot. Subsequently, the outcomes could be useful for versatile applications, including identifying additional locations for invasion by *Lantana* and in conjunction with additional data such as the distribution of vulnerable ecosystems or biodiversity hotspots, selecting regions of priority for management. The present case study further emphasizes that specific approaches for restoration of degraded fallow ecosystems are inherently site as well as case specific.

2. Materials and Methods

2.1. Study sites

The present study was conducted in Mizoram, a part of Indo-Burma biodiversity hotspot in India (**Figure 2**) and carried out during July, 2018 to September, 2021 for floristic as well as ecological survey including protected areas. Only 6.75% of the geographical area of the state comes under protected area networks. Temperature range during the March-May (summer) stays around 18-29°C whereas during August-December (winter) low temperature range (11–24°C) persist. The rainfall profile exhibits annual rainfall of 2160 mm to 3500 mm.

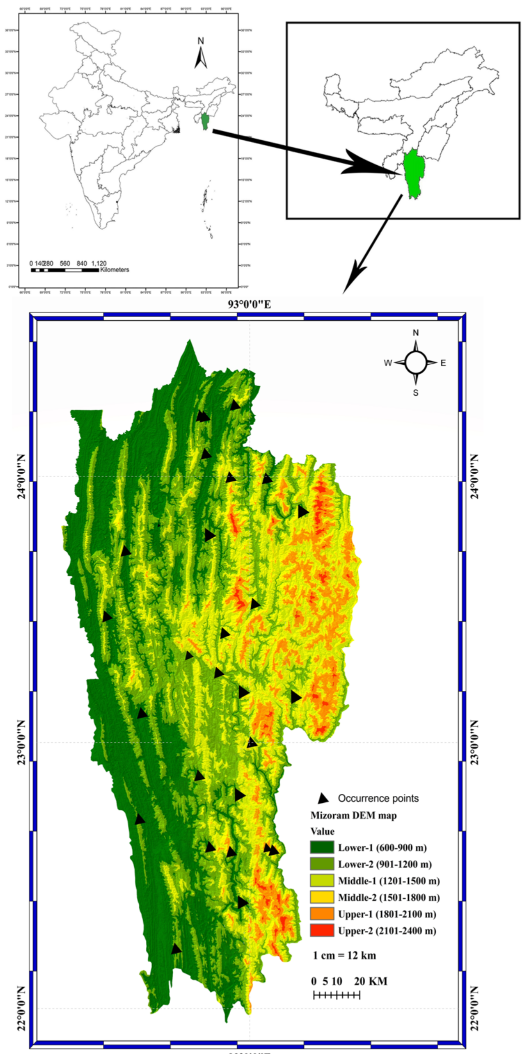

Figure 2. Digital elevation map of Mizoram with studied occurrence points of *Lantana camara*.

Six study sites were selected in different protected areas viz., Phawngpui national park (50 km^2), Murlen national Park (100 km^2), Dampa Tiger Reserve (500 km^2), Lengteng Wildlife Sanctuary (50 km^2) and also in non–protected areas viz. three- to five-year-old shifting cultivation fields near Sangau and Vapar (hereafter PNP, MNP, DTR, LWS, SAN and VPR respectively). These study sites were divided into three altitudinal zones viz. Dampa Tiger Reserve, Aizawl in Lower hills (up to 1200 m), Murlen National Park, Sangau in middle hills (1201–1800m) and Lengteng Wildlife Sanctuary, Phawngpui National Park in middle to upper hills (1201–2300 m). PNP is located in south–east Mizoram near western side of Chhimtuipui River and holds the highest point in Mizoram, Phawngpui peak (2157 m). MNP located in the Champhai district, LWS lies in eastern Mizoram, north of Murlen National Park and includes the second highest peak (2141 m), DTR is a reserve forest situated in Western Mizoram near West Phaileng at an altitudinal range of 800–1,100 m. Sangau is a fringe village near PNP and Aizawl is a growing urban area with highly disturbed forests.

2.2. Phytosociological assessment

The species occurrence data for *Lantana camara* was collected through field investigation during the field surveys and the occurrence co-ordinates were recorded using Garmin Montana 680. All the occurrence points were embedded in the digital elevation map of the study area using ArcGIS tool (ArcMap 10.8.2). The phytosociological data was collected in quantitative manner from randomly selected study plots along altitudinal gradient in both the national parks following stratified random sampling with nested quadrat technique. The study areas were laid with 1 km × 1 km grid size and among the grids, plots of 400 m^2 were randomly chosen where the phytosociological data were documented in a nested manner along altitudinal gradient. Within the selected 400 m^2 plots; 5 m × 5 m quadrats for shrub layers and 1 m × 1 m quadrats for herb layers were laid [13, 14]. Total species count in each plot, along with any associated native or invasive species, were recorded. Phytosociological data including relative frequency, relative densities, relative dominance of the species in a quadrat were determined using standard formulas (Mishra, 1968). Importance Value Index (IVI) was determined by addition of the relative values of density, dominance and frequency [15]. The study plots were chosen along 300 m altitudinal gradient from lower (up to 1200 m); middle 1201-1800 m) and upper (1801- 2400 m) gradients.

The phytosociological data were calculated as follows:

$$\text{Density} = \frac{\text{No. of individuals of a species}}{\text{Total No. of quadrats studied}} \tag{1}$$

$$\text{Frequency (\%)} = \frac{\text{No. of quadrats of occurence of a species}}{\text{Total number of quadrats studied}} \times 100 \tag{2}$$

$$\text{Abundance} = \frac{\text{Total No. of individuals of a species}}{\text{Number of quadrats of occurrence}} \tag{3}$$

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Frequancy of all the secies}} \times 100 \tag{4}$$

$$\text{Relative Density} = \frac{\text{Density of a species}}{\text{Density of all the species}} \times 100 \tag{5}$$

$$\text{Relative Dominance} = \frac{\text{Basal area of a species}}{\text{Basal area of all species}} \times 100 \tag{6}$$

Basal area = πr^2, where, π = 3.14 and r = radius of the species.

Importance Value Index (IVI) = Relative Frequency + Relative Density + Relative Dominance

Importance Value Index (IVI) was calculated separately for each species of the community. A particular species, that having highest value of importance value index (IVI) is considered as most dominant in the area and the species with lowest importance value is considered as the least dominant.

Diversity indices for the protected area study sites were calculated as follows:

$$\text{Simpson's Diversity Index (SDI)} = 1 - \frac{\sum n(n-1)}{N(N-1)} \tag{7}$$

Where, n is the number of individuals displaying one trait (e.g., the number of individuals of one species); N = the total number of all individuals [16].

The Shannon-Wiener information index (H') [17] was determined by,

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \tag{8}$$

Where the proportion of species i relative to the total number of species (pi) is calculated, and then multiplied by the natural logarithm of this proportion (ln pi). To understand the percentage of common species between study sites, index of similarity [18] were calculated as follows:

$$\text{Index of similarity} = \frac{C}{a+b+c} \quad (9)$$

Where "C" is the number of common species to both sites, "a" is the number of species unique to first site; "b" is the number of species unique to second site.

3. Results

3.1. Ecological impact of Lantana invasion

A total of 74 plants species were found from six study sites namely PNP, MNP, DTR, LWS, SAN & VPR (**Table 1**) belonging to 68 genera and 30 families. Herbs were the dominant habit (60%) followed by shrubs (26.67%) and climbers (13.33%). The most dominant family was represented by Asteraceae with 18 species belonging to 16 genera (**Figure 3**).

Table 1. Floristic composition and Importance value index of plant species in different sites.

Name of the plant	Family	Habit	PNP	MNP	DTR	LWS	SAN	VPR
Acmella radicans (Jacq.) R.K.Jansen	Asteraceae	H	15.75	22.17	22.36	–	12.37	–
Aeschynomene americana L.	Fabaceae	H	17.74	–	22.77	–	21.8	–
Ageratina adenophora (Spreng.) R.M.King & H.Rob.	Asteraceae	H	63.45	59.3	60.78	60.02	71.19	55.6
Ageratina riparia (Regel) R.M.King & H.Rob.	Asteraceae	H	43.25	34.47	–	46.04	59.52	–
Ageratum conyzoides (L.) L.	Asteraceae	H	15.02	–	10.22	16.77	9.36	28.39
Ageratum houstonianum Mill.	Asteraceae	H	–	27.05	28.51	16.52	10.65	–
Ainsliaea latifolia (D.Don) Sch.Bip.	Asteraceae	H	7.34	–	–	14.79	–	–
Alternanthera sessilis (L.) R.Br. ex DC.	Amaranthaceae	H	–	–	–	17.95	19.77	22.96
Amaranthus spinosus L.	Amaranthaceae	H	–	2.33	–	–	19.89	–
Artemisia nilagirica (C.B.Clarke) Pamp.	Asteraceae	SH	–	3.87	8.62	–	–	–
Bidens pilosa L.	Asteraceae	H	14.52	24.69	–	15.21	26.6	23.69
Brachystemma calycinum D. Don	Caryophyllaceae	H	16.07	–	–	–	–	–
Buddleja macrostachya Benth.	Scrophulariaceae	SH	22.38		–	–	12.55	–
Canscora andrographioides Griff. ex C.B.Clarke	Gentianaceae	H	–	5.27	–	24.11	–	–
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	SH	55.01	61.99	42.68	39.35	45.18	64.74
Cissampelos pareina L.	Menispermaceae	CL	7.25	–	–	–	–	–
Cleome viscosa L.	Cleomaceae	H	–	19.45	9.23	–	–	–
Clerodendrum infortunatum L.	Lamiaceae	SH	41.37	31.33	–	–	31.16	30.12
Colebrookea oppositifolia Sm.	Lamiaceae	SH	22.17	–	–	38.11	–	–
Commelina benghalensis L.	Commelinaceae	H	18.96	–	7.35	–	–	12.83
Crassocephalum crepidioides (Benth.) S.Moore	Asteraceae	H	17.74	25.31	19.38	–	9.66	–
Cuscuta reflexa Roxb.	Convolvulaceae	CL	3.29	–	–	–	2.14	18.83
Cyrtococcum accrescens (Trin.) Stapf	Poaceae	H	–	–	15.14	–	–	8.05
Cyrtococcum patens (L.) A.Camus	Poaceae	H	–	–	–	–	5.26	13.87
Digitaria sanguinalis (L.) Scop.	Poaceae	H	17.74	–	–	–	3.82	–
Emilia sonchifolia (L.) DC. ex DC.	Asteraceae	H	5.33	16.64	–	–	16.65	–
Eragrostiella bifaria (Vahl) Bor	Poaceae	H	17.97	–	–	–	–	7.21
Erigeron karvinskianus DC.	Asteraceae	H	9.27	–	–	–	25.29	14.37
Euphorbia heterophylla L.	Euphorbiaceae	H	5.65	–	–	4.68	–	–
Fagopyrum esculentum Moench	Polygonaceae	H	4.32	–	–	17.23	–	–
Galinsoga parviflora Cav.	Asteraceae	H	23.31	–	16.22	9.17	–	15.02
Galium elegans Wall.	Rubiaceae	H	–	–	–	–	6.29	11.07
*Hedychium villosum*Wall.	Zingiberaceae	SH	8.25	–	27.35	–	–	–
Hypericum elodeoides Choisy	Hypericaceae	H	–	4.46	8.49	–	–	6.88
Hypoestes phyllostachya Baker	Acanthaceae	H	17.32	–	10.04	–	26.7	–
Mesosphaerum suaveolens (L.) Kuntze	Lamiaceae	H	–	27.34	–	–	–	–
Imperata cylindrica (L.) Raeusch.	Poaceae	H	10.29	–	8.62	26.71	–	20.49
Inula eupatorioides Wall. ex DC.	Asteraceae	SH	5.37	12.3	31.71	–	9.21	–
Ipomoea alba L.	Convolvulaceae	CL	8.57	–	–	–	–	26.27
Ipomoea cairica (L.) Sweet	Convolvulaceae	CL	11.32	–	5.31	24.03	38.57	7.02
Ipomoea eriocarpa R. Br.	Convolvulaceae	CL	22.76	26.69	–	–	–	–
Ipomoea hederifolia L.	Convolvulaceae	CL	4.38	25.98	–	37.78	–	–

Table 1 continued

Name of the plant	Family	Habit	PNP	MNP	DTR	LWS	SAN	VPR
***Lantana camara* L.**	Verbenaceae	SH	**43.11**	**47.1**	**20.06**	**29.35**	**31.22**	**35.12**
Laphangium luteoalbum (L.) Tzvelev	Asteraceae	H	14.48	–	–	13.62	–	13.74
Lepidagathis incurva Buch. Ham. ex D.Don	Acanthaceae	H	2.38	–	14.11	–	5.32	–
Lobelia nummularia Lam.	Campanulaceae	H	4.35	4.19	4.25	–	6.59	5.54
Luculia pinceana Hook.	Rubiaceae	SH	–	–	24.85	–	–	–
Ludwigia adscendens (L.) H.Hara	Onagraceae	H	7.22	–	–	–	–	20.21
Maesa chisia D.Don	Primulaceae	SH	8.32	–	18.42	–	33.96	11.51
Melastoma malabathricum L.	Melastomataceae	SH	10.44	–	8.92	12.77	–	25.24
Microglossa pyrifolia (Lam.) Kuntze	Asteraceae	CL	6.49	8.35	12.19	5.32	–	7.58
Mikania micrantha Kunth	Asteraceae	CL	36.72	–	39.75	36.93	37.17	25.19
Mimosa pudica L.	Fabaceae	H	–	27.19	25.33	–	25.9	14.51
Mucuna pruriens (L.) DC.	Fabaceae	CL	–	11.39	–	9.20	–	27.02
Mussaenda roxburghii Hook.f.	Rubiaceae	SH	–	–	23.89	27.23	–	–
Oplismenus burmannii (Retz.) P.Beauv.	Poaceae	H	–	–	–	–	–	15.29
Oxalis corniculata L.	Oxalidaceae	H	17.33	–	17.51	–	11.52	7.25
Persicaria chinensis (L.) H. Gross	Polygonaceae	H	10.17	20.36	–	–	8.15	–
Phlogacanthus thyrsiflorus Nees	Acanthaceae	SH	35.85	–	–	12.32	–	34.12
Physalis angulata L.	Solanaceae	SH	16.58	–	–	–	2.38	–
Plantago major L.	Plantaginaceae	H	2.56	5.82	9. 38	–	15.12	–
Rubus ellipticus Sm.	Rosaceae	SH	15.11	–	–	26.59	39.57	–
Saccharum spontaneum L.	Poaceae	H	–	19.59	–	–	6.21	28.52
Scoparia dulcis L.	Plantaginaceae	H	14.75	–	8.75	–	12.53	–
Senna alata (L.) Roxb.	Fabaceae	SH	17.72	–	26.02	–	–	21.09
Setaria pumila (Poir.) Roem. &Schult.	Poaceae	H	–	18.39	–	–	–	–
Sida acuta Burm.f	Malvaceae	H	11.85	–	17.13	10.27	–	21.38
Smilax roxburghiana Wall. ex A.DC.	Smilacaceae	CL	–	–	–	–	12.39	–
Solanum torvum Sw.	Solanaceae	SH	–	35.45	8.27	–	–	18.53
*Stellaria media (*L.) Vill.	Caryophyllaceae	H	7.77	–	–	8.21	5.22	–
Strobilanthes atropurpurea Nees	Acanthaceae	H	12.05	–	11.21	–	–	–
Tithonia diversifolia (Hemsl.) A.Gray	Asteraceae	SH	–	21.38	–	17.60	19.15	17.02
Urena lobata L.	Malvaceae	SH	–	33.09	–	–	11.28	–
Viola pilosa Blume	Violaceae	H	3.51	–	5.07	–	4.41	–

Abbreviations: PNP-Phawngpui National Park, MNP–Murlen National Park, DTR–Dampa Tiger Reserve, LWS–Lengteng Wildlife Sanctuary, SAN–Sangau & VPR–Vapar; H–Herb, SH–Shrub, CL–Climber.

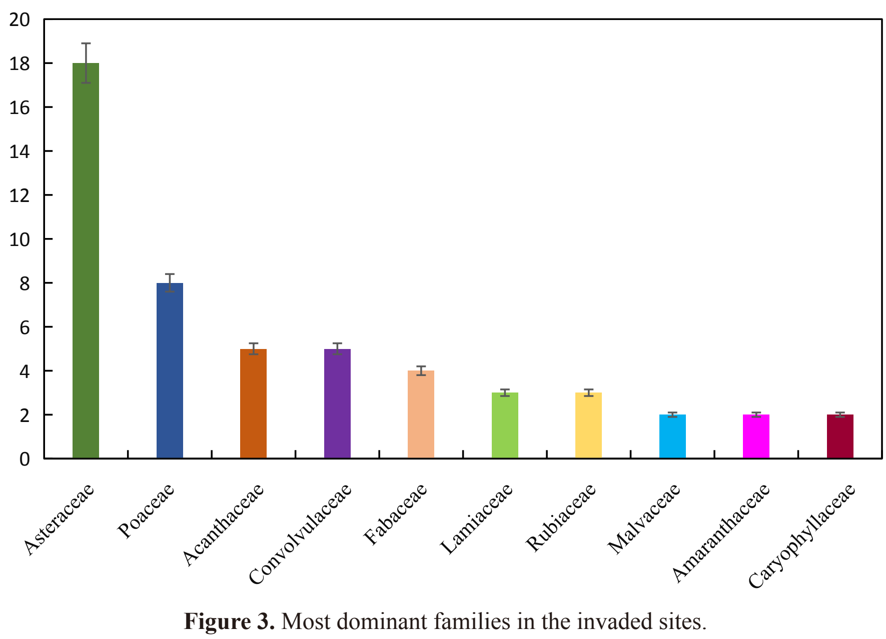

Figure 3. Most dominant families in the invaded sites.

Lantana camara, *Chromolaena odorata* and *Mikania micrantha* were observed as the most dominant alien plants in the shrub layers while *Ageratina Adenophora* were the most dominant alien plants in the herb layers of the studied invaded natural forest sites in PNP, MNP, DTR, LWS, SAN and VPR. *Lantana camara* was one of the predominant shrubs in the invaded natural forest in lower to middle altitudes (up to 1600 m) in all the study sites. Highest dominance of *Lantana camara* was observed in MNP (IVI–47.1) at 1370 m followed by PNP (IVI–43.11) at 1560 m, VPR (IVI–35.12) and SAN (IVI–31.22) at 1600 m. In all the six study sites, *Lantana camara* was not observed beyond 1600 m altitude. Phytosociological assessment in shrub layer revealed *Chromolaena odorata* to be the most dominant species in VPR (IVI–64.74) and MNP (IVI–61.99) followed by PNP (IVI–55.01) and DTR (IVI–45.68). In herb layers, the dominant alien plant *Ageratina adenophora* was observed in SAN (IVI–71.19) and PNP (IVI–63.45) followed by DTR (IVI–60.78) and LWS (IVI–60.02) (**Table 1**).

Maximum number of species was observed in PNP with 53 species under 48 genera and 24 families while least diversity was observed in LWS with 28 species belonging to 25 genera and 16 families. Dominance of *Ageratina adenophora* (IVI–63.45) with co–dominants like *Ageratina riparia (*IVI–43.25), *Hypoestes phyllostachya* (IVI–17.32) were observed in PNP herb layer, while in shrub layer, *Chromolaena odorata* (IVI–55.01) was most dominant followed by *Lantana camara* (IVI–43.11) and *Mikania micrantha* (IVI–36.72). In MNP, *Lantana camara* invaded study sites exhibited IVI value of 47.10 and a species richness of 30 species exhibiting an invasion impact by alien plants on co-associated native species like *Microglossa pyrifolia* (IVI–8.35), *Artemisia nilagirica* (IVI–3.87), *Hypericum elodeoides* (IVI–4.46) and *Lobelia nummularia* (IVI–4.19).

The values of diversity index H′ ("Shannon diversity index") for the invaded shrub layers of natural forests in Phawngpui national park (PNP) was highest (H′= 4.461) and least in Lengteng wildlife sanctuary (H′=3.814) along the lower to middle altitudinal gradient up to 1600 m. Phytosociological assessment along altitudinal gradient of the invaded shrub layers also revealed highest value of Simpson's index (D–0.951) from PNP whereas the lowest value was observed in MNP (D–0.890).

Evaluation of similarity indices (**Table 2**) in various altitudinal ranges revealed that PNP in upper hills possessed 46.25% similarity to SAN in middle hills, 35.61% and 37.28% similarity to DTR and VPR respectively. Among the protected areas situated in lower and middle hills, low similarity of 20.45% was observed between DTR and MNP with different altitudinal range whereas 41.57% similarity was observed between MNP and Sangau.

Table 2. Similarity Indices among the six study sites in Mizoram.

Site Name	PNP	MNP	DTR	LWS	SAN
PNP	–	–	–	–	–
MNP	21.76	–	–	–	–
DTR	35.61	20.45	–	–	–
LWS	37.28	21.31	25.38	–	–
SAN	46.25	41.57	28.10	23.30	–
VPR	38.21	25.72	37.25	35.15	34.45

3.2. Socio-Economic uses and management

An interactive semi-structured interview with the local people and farmers revealed that the freshly collected leaves are used as antimicrobial and nematocidal. Leaf extract is used as antiseptic in cuts and wounds. In Dampa and Sangau, the dried stems are used for preparing basket and firewood. In Thaltlang and Cheural, fresh leaf paste is used as a poultice for rheumatic joints to reduce pain. In Hnahlan and Ngur, leaf infusion is prepared along with leaves of *Cymbopogon citratus* and the infusion is taken orally to control blood pressure and stabilize malarial fever.

For removal of the *Lantana camara* thickets, the locals follow manual weeding or mechanical removal of roots by sharp tools and burning of residues of the plant. Although mechanical removal management practices show promising outcomes before cultivation, fallow lands are not managed afterwards making it vulnerable to invasion. Regardless of having serious ecological repercussions, Utilization of *Lantana camara* in local livelihood generation in the socio–economic purpose is a sustainable way of management for invasion in lower and middle altitude of Mizoram.

4. Discussion

Pervasive presence of *Lantana camara* in six studied sites was revealed by the phytosociological assessments throughout the herb and shrub layers up to the middle altitude (1600 m). A greater risk of invasive encroachment by this invasive species was observed throughout lower gradient altitudinal zones. In shrub layer, *Lantana camara* was observed to be associated with the dominant *Chromolaena odorata* and *Mikania micrantha*. A similar association of *Lantana camara* with other invasive alien plants were also reported from Uttar Pradesh, tropical and sub-tropical zones of the Indian Himalayan region [4]. *Lantana camara* invasion was also reported for its negative impacts on the forest ecosystems in India [6]. As per our observation, due to its increased proliferation aided by seed dispersal by frugivorous birds and high vegetative reproductive ability aggravate the invasion scenario in lower to middle altitudinal gradient in Mizoram. Our findings are also in congruence with previous reports from Southern India [19], Western Himalaya [20] and Andhra Pradesh [21].

Figure 4. (A). Habit of *Lantana camara*; Invasive spread of *Lantana camara* in **(B)**. Natural forests of Phawngpui national park at 1247 m a.s.l. in Mizoram; **(C)**. Trail path of Murlen national park at 1182 m ; **(D)**. Degraded landscape near Lengteng wildlife sanctuary at 1157 m.

The phytosociological assessment revealed that abundant invasive spread of *Lantana camara* decreases along the increasing altitude and peak invasion was observed at 900-1350 m altitudinal range. The IVI varied from lowest at DTR (IVI-20.06) to highest at MNP (IVI-47.10). Similar observations of decreasing IVI of *Lantana camara* with increasing altitude was also reported from the invaded landscapes of Doon-valley [22]. A recent study on the potential habitat distribution modelling on the invasion of *Lantana camara* in Western Ghats [23] also reported the influence of altitudinal range on the invasion spread the species.

Pattern of the species richness and diversity indices also indicated that the *Lantana* invaded areas exhibited reduced species richness compared to uninvaded natural forests (Figure 4). Similar report of gradual decrease in species richness and associated native species was observed in lower Siwalik Hills of Northern India [24]. Overall, invaded locations exhibited significantly reduced plant richness, diversity, and overall health in comparison to non-invaded areas. This decline could be linked to the dense pure stands of *L. camara*, altering the microenvironment beneath its thickets, affecting factors such as light, pH, and temperature, thereby impeding the germination or growth of other species [25]. Impact of *Lantana camara* invasion on the Shannon's diversity index (H′) and Simpson's index (D) value was also observed in Uttarakhand, India [26]. In *Lantana* invaded areas, the likelihood of occurrence associated native species frequently diminished compared to uninvaded areas.

Locals also informed that decoction of fruits and leaves are used as lotion for wounds. The dried shoots of *Lantana* are extensively used for preparation of packaging and basket for transportation of fresh vegetables. A similar antimicrobial use of *Lantana camara* was reported from Madagascar [27] and India [28]. Similar uses of *Lantana camara* were also reported from Uttarakhand [4].

5. Conclusions

This case study delves into the ecological consequences of the invasion of *Lantana camara* in natural forests, shedding light on its invasive nature, economic applications and eradication strategies in Mizoram. The negative impacts of *Lantana* invasion extend to forests, agricultural terrains, and fallow lands, resulting in biodiversity degradation and adverse effects on native flora management. *Lantana* thickets also serve as catalysts for forest fires. Conversely, its antimicrobial and antiseptic properties hold significant potential for positive uses. Furthermore, the utilization of dry *Lantana* shoots in traditional basket weaving presents viable prospects for industrial applications. Rather than pursuing complete eradication, we advocate for managing *Lantana* to mitigate its effects through cost-effective methods. It is pertinent to emphasize the positive aspects and economic benefits of *Lantana* which may outweigh its negative impacts. Removal of *Lantana* alleviates resource competition, enabling opportunistic herbaceous growth and native plant colonization suggesting that timely management fosters healthier native flora growth. Studies akin to this one are imperative for understanding forest recovery potential amidst *Lantana* invasion, emphasizing the necessity of assessing cost-effectiveness in management strategies.

Author Contributions

R.S. (PhD student and first author) contributed in the plant sample collection, identification, field work and data analysis of the data and drafted the paper. S.S.D. contributed to validation of the data, methodology preparation and contributed to critical reading of the manuscript. All the authors have read the final manuscript and approved the submission.

Conflict of Interest

The authors express no conflict of interest.

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