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The Advancing Dominance of *Ageratum conyzoides* L. and *Lantana camara* L. in a dry Tropical Peri-urban Vegetation in India

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Abstract

The growing significance of Lantana camara and Ageratum conyzoides in dry tropical peri-urban vegetation was investigated to assess their impact on vegetation structure and soils. While Ageratum occurred at about 85% of the sampled locations, Lantana was at only 26%. The phytosociological analysis of two Ageratum infested sites LTI (long-term recurrently infested) and STI (short-term infested) showed the presence of 46 angiospermic flora in total, distributed over 24 families (23 dicot and 1 monocot), 40 at LTI and 23 at STI. Ageratum and Cynodon dactylon were the leading dominants at both sites accounting for 57% at LTI and 70.3% at STI in terms of IVI. However, in terms of biomass contribution by Ageratum alone, it accounted for 70.8% of total plant biomass at LTI and 82.9% at STI site. The similarity between the plant communities at these two sites in terms of Sorenson index was 0.63. The soils at LTI site showed higher moisture content, total Nitrogen and Organic Carbon (%) compared to STI. However, available P, S, Zn, Fe, Mg, Cu and exch. K were comparable at both sites. Diversity was also higher at LTI site. The dominance-diversity curve of the plant communities at STI and LTI sites showed geometrical pattern of resource share. In conclusion, the structure of peri-urban vegetation, diversity and soils are greatly impacted by the invading species Lantana camara and Ageratum conyzoides in Indian dry tropics, by virtue of superior dry matter build-up capacity.

Keywords: Peri-urban vegetation, Dry-tropics, Invasive, IVI, Diversity, Soils

Introduction

The plant invasions, a significant component of global change[1,2] are presently viewed with great ecological concern[3], that are reported to occur largely as a result of human activities due to higher rate of introductions and spread of exotic species[4,5]. Such alien invasions may often have highly deleterious effects on the ecosystem structure and functioning[1,2,5] and native biodiversity[6] which consequently impacts the stability of the ecosystems[7]. These invasive species are predicted to have traits that favour efficient use of resources[8,9].

The heterogeneity in urban and semi-urban environment is reported to greatly impact the plant survival and establishment in this region[10]. The peri-urban areas that cater to the developmental needs of the urbanizing landscapes in the vicinity are considered highly important and dynamic both ecologically as well as economically[11]. Such areas characterized by continuous disturbance are likely to witness invasions by alien species[12]. The floristic composition in such disturbed areas is often much different compared to semi-natural, natural and man-made ones outside cities[13] that alters with time, giving rise to a particular species pattern and behaviour, community formation and its population dynamics, that may be specific to the urban environment[14]. The mosaic of peri-urban vegetation has been reported to correspond to the multiplicity of land-uses, predominantly composed of weeds and ruderals, which appear to have naturalized with the passage of time under persistent anthropogenic activities[15]. Such areas have witnessed large-scale intrusion by exotic invasive species that include some of the worst invasive species of the world eg. *Parthenium hysterophorus*, *Lantana camara* and *Ageratum conyzoides*. While relatively much ecological information exists on *Parthenium hysterophorus*, such authentic information on intrusions and impacts of *Ageratum conyzoides* (hereafter *Ageratum*) and *Lantana camara* (hereafter *Lantana*) in Indian dry-tropics is generally lacking.

A comprehensive study on the peri-urban vegetation in Indian dry tropical region of Bulandshahr aimed to: i. assess the frequency of the distribution of *Ageratum* and *Lantana*, ii. assessing the species composition, dominance, diversity and soil properties of the vegetation infested by these two exotic species.

Material and Methods

Study area: The study area in the western part of Uttar Pradesh was located at Bulandshahr ($28^0 04'$ and $28^0 43'$ N lat. and $77^0 08'$ and $78^0 28'$ E long.) (figure 1). It lies within the Ganga basin, India. The vegetation, here, is mainly comprised of mosaic of annual weeds and ruderals. Two *Ageratum*-infested study sites, representing contrasting habitat conditions of area $1 km^2$ each were selected for the present study. The first site, designated as long-term and recurrently-infested site (LTI), was located near Gang Nahar canal along Khurja road. It experienced over eighteen years of recurrent infestations by *Ageratum*. The vegetation, here, was relatively species-rich and faced relatively low disturbance by humans and grazing animals. The second site, the shortly-invaded/short-term (3-4 years) infested site (STI), was located in the midst of long fallow land, which has recently begun to witness human colonization activities. Fruit orchard and a railway track lay in the vicinity of this study site. It was relatively more human-interfered and disturbed. The climate of the study area is semi-arid. The mean maximum and minimum temperature recorded during the study period (2009-2011) were 30.8ºC and 18.5 ºC respectively and the mean rainfall recorded was 51.8 mm.

Plant sampling: The species composition of the study sites was recorded from September to March during the study period (2009-2011). The identification of the plant species was done according to the available floras[16,17]. For understanding the intrusion and spread of *Ageratum* and *Lantana* an extensive survey was conducted by recording their density and frequency of occurrence at every 200 m for a distance of about 20 km each along i. Jahangirabad road towards Anoopshahr, ii. Siyana road towards Garh, iii. Khurja road towards Aligarh, iv. Sikandrabad road towards Delhi, and v. Gulaothi road towards Meerut. The phytosociological analysis was carried out at two *Ageratum* infested sites. The data were obtained from a total of 40 quadrats laid randomly (each 25 cm × 25 cm), distributed across two selected study sites. They were: (1) long-term infested site that witnessed recurrent *Ageratum* infestation for about 20 years (LTI) and (2) short-term (1-3 years) infested site (STI). For density estimation of grasses every emergent tiller was considered as one individual. Total plant biomass (above- and below-ground) estimated[15] was used as a dominance measure in the estimation of species IVI (Importance Value Index) [18] and the species relative importance value index (RIVI) was calculated as IVI/3[19].

Similarity Coefficient: Sorenson similarity coefficient (SC)[20] was estimated according to the following formula to calculate the similarity between the two study sites:

$$SC = \frac{2\,jN}{aN + bN}$$

jN = sum of lesser values of IVI in two sites; aN = sum of IVI of all species in LTI site; bN = sum of IVI of all species in STI site.

Dominance-diversity structure: Dominance-diversity curve was prepared by plotting species RIVI and relative dominance against the species sequence (high to low RIVI) [21].

Species diversity: α diversity of each study site was calculated in terms of seven indices. Different symbols used in their calculations included: S = total number of species, N = total sum of IVI of all species, pi = proportional IVI of ith species (ni/N), ni = IVI of each species and Nmax = IVI of the most important species.

Species richness indices: Species count (Number of species/area) (nunber of species that occurred in quadrats sampled)

Margalef index[22] = $\frac{S-1}{\ln N}$

Menhinick index[23] = $\frac{S}{\sqrt{N}}$

Information statistic indices: Shannon-index (H') [24] = $-\sum pi \ln pi$

Evenness[25] = $\frac{H'}{\ln S}$

Dominance measures:

Berger-Parker index[26] = $\frac{N_{\max}}{N}$

Simpson index[27] = $\sum pi^2$

β diversity: β diversity was estimated within vegetation at a study site by dividing the total number of species at a site by the average number per sample[28].

Soil analysis: Eight samples of surface-soils (0-10 cm) were collected randomly from each site in the months of February, May and October, they were air-dried and sieved (2 mm). The physico-chemical characteristics of these soils estimated were: soil moisture content, pH, total Organic Carbon (Walkley and Black method), total N (micro-Kjeldahl's method)[29]; available Phosphorous and exchangeable Potassium[30]. Various micro-nutrients like available Sulphur, Zinc, Iron, Magnesium and Copper were estimated at the District soil testing lab in Bulandshahr[29].

Results and Discussion

Abundance of the exotic invasives *Lantana* and *Ageratum*: While *Ageratum* occurred at about 85% of the sampled locations, *Lantana* frequency was only 26% (table 1). The frequency of *Ageratum* varied from 77.3% (along Khurja road) to 91.3% (along Siyana road). On the other hand, relatively much less frequently found *Lantana* varied from 13.3% (along Sikandrabad road) to 41% (along Khurja road).

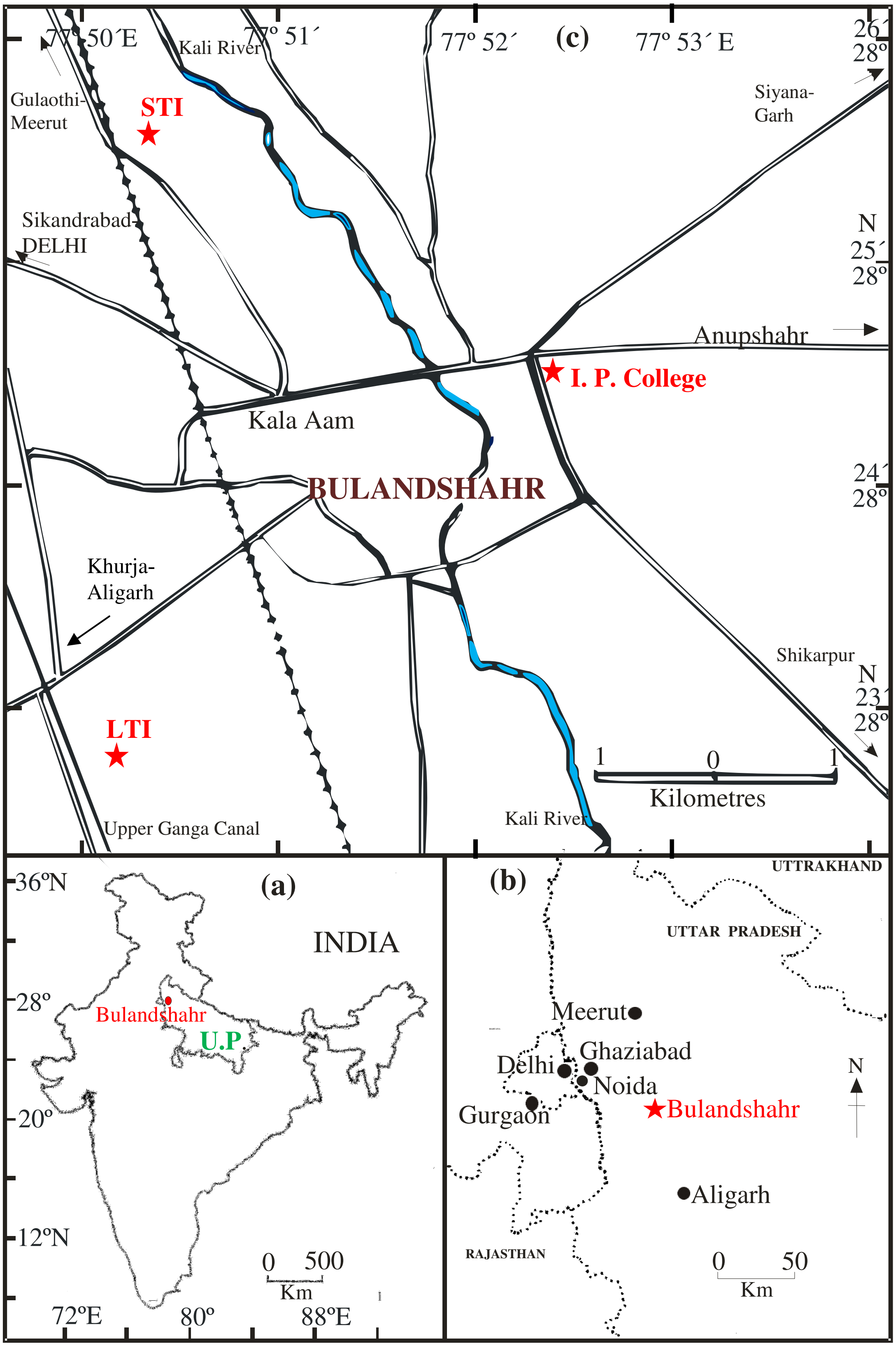

Figure-1

(a) Location of study area, (b) Peri-urban region of Bulandshahr surrounded by some developed urban centres and (c) Study site: codes LTI {long-term and recurrently infested site (15-20 years)}, STI {short-term (1-3 years) infested site}

Table-1
Density (D), Frequency (F) of *Ageratum conyzoides* and *Lantana camara* along the roadside vegetation in a dry tropical peri-urban region. The distance in parentheses indicates the length sampled from Bulandshahr city

Distance covered (km)	*Ageratum conyzoides*		*Lantana camara*	
	D (m^{-2})	F (%)	D (km^{-2})	F (%)
Anoopshahr Rd. (18 km) in East	10.3	83.67	2.2	33.67
Garh Rd. (16 km) in North-east	12.8	91.33	1.4	24.00
Aligarh Rd. (21 km) in South	09.7	77.33	3.2	41.00
Delhi Rd. (14 km) in West	11.6	85.67	1.0	13.33
Meerut Rd. (17 km) in North	11.3	85.00	1.0	17.00
Mean	11.1	84.60	1.8	25.80

Floristic composition: In all, 46 angiospermic plant species, predominantly annuals, distributed over 24 families (23 dicot and 1 monocot) were recorded in the present study. Maximum number of species was recorded at LTI site (40) compared to only 23 recorded at STI site. The larger families were Poaceae (6), Malvaceae (5), Asteraceae (4), Euphorbiaceae (4), Amaranthaceae (3), Solanaceae (3), Caryophyllaceae (2), Leguminosae (2) and Polygonaceae (2).

Species dominants: On the basis of IVI, top leading dominants at both LTI and STI sites were Ageratum followed by Cynodon dactylon that accounted for 57% and 70.3% of total species IVI respectively (table 2). However, in terms of biomass contribution by Ageratum alone, it accounted for 70.8% of total biomass at LTI site and 82.9% at STI site. The other sub-dominants in terms of IVI at LTI site included Rostellularia procumbens, Oxalis corniculata and Malvastrum tricuspidatum, and at STI site Euphorbia hirta, Dactyloctenium aegypticum and Xanthium strumarium. The similarity between the plant communities at these two sites in terms of Sorenson index was 0.63.

Table-2
Dominant species composition at two *Ageratum*-infested sites (long-term recurrently infested, LTI and short-term infested, STI) in a peri-urban region in Indian dry tropics. Top 14 dominant species of each site are shown. Code: Relative density (RD), relative dominance in terms of total plant biomass (RDo.), relative frequency (RF) and importance value index (IVI).

Species	LTI site				STI site			
	RD	R Do.	RF	IVI	RD	R Do.	RF	IVI
Ageratum conyzoides	6.45	70.80	11.63	88.88	14.03	82.86	16.67	113.55
Alternanthera sessilis	-	-	-	-	1.36	0.11	5.00	6.46
Amaranthus viridis	-	-	-	-	0.90	0.08	3.33	4.31
Cannabis sativa	2.73	0.89	1.16	4.78	1.81	0.43	5.00	7.24
Cornopus didymus	-	-	-	-	0.90	0.02	3.33	4.26
Croton bonplandianum	-	-	-	-	0.90	0.30	3.33	4.54
Cynodon dactylon	51.86	18.76	11.63	82.24	65.61	14.67	16.67	96.95
Cyperus rotundus	0.99	0.17	3.49	4.65	-	-	-	-
Dactyloctenium aegypticum	-	-	-	-	1.81	0.02	5.00	6.83
Digitaria abscendens	0.74	0.49	2.33	3.56	-	-	-	-
Euphorbia hirta	-	-	-	-	2.26	0.06	6.67	8.99
Euphorbia thymifolia	-	-	-	-	1.36	0.02	5.00	6.37
Lantana camara	0.50	0.16	2.33	2.99	-	-	-	-
Malva sylvestris	0.50	0.26	2.33	3.08	-	-	-	-
Malvastrum tricuspidatum	3.23	0.86	5.81	9.90	-	-	-	-
Oxalis corniculata	5.96	0.76	4.65	11.37	-	-	-	-
Parthenium hysterophorus	-	-	-	-	0.90	0.04	3.33	4.28
Rostellularia procumbens	13.65	1.74	4.65	20.04	-	-	-	-
Setaria glauca	0.99	1.17	3.49	5.65	-	-	-	-
Sida acuta	1.24	0.95	3.49	5.68	-	-	-	-
Solanum nigrum	1.49	0.03	3.49	5.01	1.36	0.01	3.33	4.70
Spergula arvensis	0.74	0.01	2.33	3.08	-	-	-	-
Xanthium strumarium	-	-	-	-	1.36	0.38	5.00	6.74
Others	8.93	2.96	37.21	49.10	4.52	1.00	15.00	20.52
Density (individuals m^{-2})	210.00	-	-	-	150.00	-	-	-
Total plant biomass (g m^{-2})	170	-	-	-	210	-	-	-
Total number of species	40.00	-	-	-	23.00	-	-	-

Other species included: *Abutilon indicum, Achyranthus aspera*, *Anagallis arvensis*, *Argemone mexicana*, *Boerhavia diffusa*, *Calotropis procera*, *Cassia occidentalis*, *Commelina benghalensis*, *Dactyloctenium aegypticum*, *Datura stramonium*, *Lathyrus odoratus*, *Mazus japonicas*, *Medicago sativa*, *Phalaris minor*, *Physalis minima*, *Polygonum barbatum*, *Ranunculus sceleratus*, *Ricinus communis*, *Rumex dentatus*, *Stellaria media*, *Tridax procumbens*, *Triumfetta rhomboidea* and *Urena lobata*.

Dominance-diversity structure: LTI was much more diverse than STI in terms of Species count, Margalef index and Menhinick index (species richness indices) (table 3). In contrast, the dominance measures (Berger-Parker and Simpson index), STI exhibited higher dominance. In terms of species evenness (Pielou), both STI and LTI communities were comparable. On the basis of information statistic index (Shannon-index) which incorporates both species evenness and richness, the LTI site plant community can be considered more diverse than STI site.

Table-3
Diversity estimates of the vegetation at the two *Ageratum*-infested sites (long-term recurrently infested, LTI and short-term infested, STI) in a peri-urban region in Indian dry tropics using different diversity indices

Diversity indices	LTI site	STI site
Species count	40.00	23.00
Margalef index	39.82	22.82
Menhinick index	2.31	1.33
Shannon-index	2.50	1.97
Evenness (Pielou)	0.68	0.63
Berger-Parker index	0.30	0.38
Simpson index	0.17	0.25
β diversity	4.88	3.83

The dominance-diversity curve of the plant communities at STI and LTI sites indicated a tendency to geometrical pattern of resource share (figure 2). The nature of the curve reflects close contest between Ageratum and Cynodon dactylon for the leading dominance. The d-d curve also shows a much larger number of tail-ending species sharing a meager resource at LTI site.

Soil characteristics: The soils at LTI site showed higher moisture content, total Nitrogen and Organic Carbon (%) compared to STI site-soils (table 4). However, available P, S, Zn, Fe, Mg, Cu and exch. K were comparable at both sites.

Table-4
Physico-chemical characteristics of soils at two *Ageratum*-infested sites (long-term recurrently infested, LTI and short-term infested, STI) in a peri-urban region in Indian dry tropics (mean ± SE)

Soil characteristics	LTI site	STI site
Moisture Content (%)	2.37 ± 0.30	1.65 ± 0.05
Total N (%)	0.06 ± 0.003	0.04 ± 0.02
pH	7.05 ± 0.06	7.39 ± 0.03
Organic C (%)	1.28 ± 0.02	0.36 ± 0.02
Available P (kg/ha)	8.87 ± 0.58	8.50 ± 0.37
Exch. K (kg/ha)	133.37 ± 3.47	130.62 ± 1.05
Available S (ppm)	11.60 ± 0.16	11.31 ± 0.11
Available Zn (ppm)	0.74 ± 0.01	0.74 ± 0.01
Available Fe (ppm)	4.97 ± 0.11	4.65 ± 0.04
Available Mg (ppm)	4.81 ± 0.02	4.73 ± 0.01
Available Cu (ppm)	0.64 ± 0.01	0.64 ± 0.01

Discussion: The present study indicated the advancing dominance of *Lantana* as well as *Ageratum* in Indian dry-tropics. The perennial *Lantana* appears to have entered the peri-urban anthropo-ecosystems in the national capital region of India. However, as revealed from the study, it has not yet attained the dominant status of recognisable prominence in and around the fertile regions of the Ganga-Yamuna Doab. Infact, ever since the entry of this aggressive weed invader in India as an ornamental plant reported for the National Botanical Garden of Calcutta in 1807[31]. Having escaped into the wild later, it has been reported to have established all over India, from the sub-montane regions of the outer Himalayas to the southernmost part of India[32]. A native of tropical America[33], *Lantana*, known as one of the world's ten worst weeds[34], has globally invaded several millions of hectares of grazing land. It has posed a serious agricultural concern for the production of 14 major crops that included coffee, tea, rice, cotton and sugarcane[35]. However, reviled as a nuisance and a menace worldwide, it has also been suggested to be of great help to humans and animals[36].

The increasing dominance of *Ageratum* in this region, on the other hand, appears to significantly alter the structure of the vegetation here. Like *Lantana*, it has also been suggested to be introduced as an ornamental plant initially in India. Primarily an annual weed of cultivated fields, it has survived well across diverse habitats that include pastures, rangelands and along water courses[37]. It has also invaded other ecosystems such as, grasslands, wastelands and even forest areas. *Ageratum* is presently considered as an established and naturalized exotic invasive weed in India[38]. Although considered as a shade-loving seasonal plant[39] dominantly occurring in regions of low temperature, the present study reflected its predominant territorial expansion in the anthropogenic regions, particularly in Indian dry tropics.

This winter annual appears to attain dominant status by virtue of efficiently utilising the scantily available soil resource in Indian dry tropics for its overall biomass build-up, as evinced by much higher plant biomass of this species particularly at shortly invaded site (table 2). It is reported to have high phenotypic plasticity that allowed it to optimize growth in alien environment through differential allocation of biomass[40]. The impact of *Ageratum* on the vegetation structure, here, is implicit from the lower plant biomass produced here. The total plant biomass range recorded in the present study (170 - 210 g m^{-2}) was much lower than 374-566 g m^{-2} of total biomass reported for various diverse anthropo-ecosystems in the peri-urban region here[15]. The AGB (above ground biomass) of herbaceous biomass was reported in the range 228 - 738 g m^{-2} in this peri-urban region[11]. It was 33-504 g m^{-2} in semi-arid grazingland of Madurai[41], and 87- 848 g m^{-2} for comparable semi-arid habitats in Jaipur[42]. In terms of density, however, *Ageratum* was strongly contested by the annual grass *Cynodon dactylon*. Several studies[15,43,44,] reported predominance of annuals in disturbed site-soils, as also found in the present study.

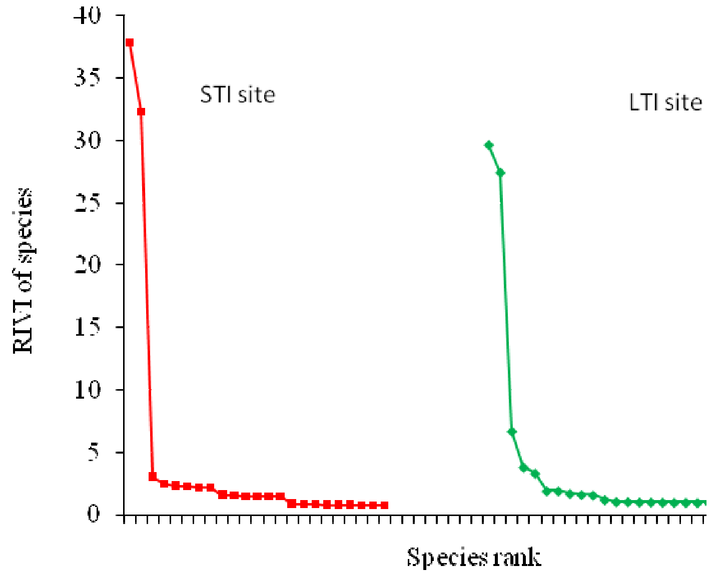

Figure-2

Dominance-diversity structure of *Ageratum*-infested plant communities at STI (short-term infested) and LTI (long-term recurrently infested) sites in a dry tropical peri-urban region

The general impact revealed by species importance value index that incorporated relative values of density, frequency and dominance, as reflected by the d-d curve (figure 2) and species dominants (table 2), showed that 70% of the IVI at STI is shared between *Ageratum* and *Cynodon* and these two species accounted for 57% of IVI share at LTI. This is evident from the enhanced tendency to geometrical pattern of resource share by these two species in the studied vegetation. The diversity of the *Ageratum* dominated vegetation here in the study was much lower than four diverse peri-urban plant communities (Shannon index 2.25- 2.78) in dry tropics reported[11], however, β- diversity lay in the range 2.36-11.21 reported by them. Lowest species diversities along the urban–rural gradient have been documented[13, 45].

LTI site was species-rich compared to STI with soils having higher moisture content, total N and organic C, indicative of nutrient-rich soils harbouring greater species diversity[15]. Despite the dominance of *Ageratum* at both the sites, diversity was lower at STI site (table 3). This possibly owes to the fact that the open areas created as a result of human activities offer equal opportunities to propagules of all species in the vicinity (e.g. nearly 63% similar species-rich LTI site) or at distance to enter a new site through transportatios. However, propagules of only a few species with greater competitive and adaptation ability finally succeed in establishment. Of the intruding new-comer species, as evinced in this study, the alien ones appear to be competitively superior, who can be considered as successful ecological opportunists and exploit the ecological resources optimally for their growth. This can be inferred from *Ageratum* accounting for about 83% of total plant biomass at the STI site, amongst the 23 species recorded in the sampled plots at this newly invaded site.

Conclusion

In conclusion, peri-urban vegetation structure and soil characteristics are greatly impacted by the invading species Lantana *camara* and *Ageratum conyzoides* in Indian dry tropics.

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