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Impact of Alien Invasive Species (*Lantana camara* L.) on Natural Regeneration and Soil Properties in Nagarahole Tiger Reserve, India

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Abstract: *Lantana camara* L. is an alien invasive species widespread in India and is considered as a serious threat to native plant biodiversity and regeneration. The present study was carried out to assess the effect of lantana invasion on natural regeneration and soil properties in two different vegetation types of Nagarahole Tiger Reserve. Four levels of lantana infestation that were highly infested, moderately infested, lantana uprooted areas and areas without lantana infestation were considered for the present study. Five sub-quadrants were laid in the main quadrate to assess the regenerates. Four soil samples were randomly collected at 0-15 cm and 15- 30 cm depths and were analysed for different physicochemical properties. Highest density of regenerates was observed in uprooted areas followed by moderately infested areas in dry deciduous forests and in moist deciduous forest types, the highest density of regenerates was observed in non-infested areas followed by uprooted areas. Maximum soil moisture, bulk density, pH and electric conductivity were observed in highly infested areas but the organic carbon percentage and organic matter was highest in non-infested areas. The higher Lantana infestation is affected by natural regeneration and Lantana uprooting is helping to improve the regeneration status.

Keywords: *Lantana camara*, Alien invasive, Diversity, Regeneration, Organic carbon

Tropical forests are well known for diverse terrestrial habitats harbouring rich biodiversity with the most significant living biomass on the other hand, these forests are under immense natural and anthropogenic pressures that have led to biodiversity loss. Invasive plant species are considered as the second most important threat to global biodiversity and habitat destruction (Bhatt et al 2011). The introduction and/or spread of alien invasive species beyond their native past or current range endangers biological diversity. Although not all imported species become invasive, they frequently become superior rivals for native species. When compared to native species, factors such as quick reproduction and development, phenotypic flexibility, strong dispersion capacity, and the ability to thrive on numerous food types and in a wide variety of environmental conditions are expected to aid in the spread of these invasives.

Lantana camara L. (Lantana) is a woody straggling shrub native to tropical America. It is listed by the Invasive Species Specialist Group as one of the 100 worst weeds in the world and has been brought into other nations as an ornamental or hedge plant. The plant is known as wild sage or red sage and belongs to the Verbenaceae family. The East India Company initially introduced it as an ornamental plant in the Royal Botanical Garden in Calcutta during 1807 and it quickly invaded throughout India, mostly in wastelands, railway tracts, and tropical woods. Reports of lantana's fast proliferation began to surface in numerous sections of the country in the early 20th century (Nagouchi and Kurniadie 2021). Lantana isa common invader of dry forest landscapes, slash-and-burn fallows and pasture lands all over India. It displays high morphological variation because of extensive breeding (Sharma et al 2005).

The Western Ghats in southern India are one of the world's twelve major biodiversity hotspots, with diverse fauna and flora. Lantana has spread throughout tropical forests, causing substantial harm by disrupting native plant variety and the nitrogen cycle process. *L. camara* has also expanded in practically all sections of Nagarahole Tiger Reserve, despite the fact that many efforts, such as hand removal and burning the invasive plant. However, it has developed its own process of infection, posing challenges to local ecological variety. With this background, the present study was carried out to through light on the effect of Lantana invasion on natural regeneration and soil properties in Nagarahole Tiger Reserve.

MATERIAL AND METHODS

Study site: The study was focused on the effect of infestation of *L. camara* on natural regeneration and soil properties in the Nagarahole Tiger reserve. It is a part of the Nilgiri biosphere reserve, lies between the latitudes 11° 58′ 25.75″ N and longitude 76° 12′7.99″ E. The Nagarahole Tiger reserve was one of the best-managed parks in the country with the highest density of both herbivore and carnivore populations. The area receives 1000 to 1540 mm annual rainfall favours the area to have high humidity with a temperature ranging between 12°C and 32°C. Elevation of the park ranges from 687 to 960 m. The total geographical area of the reserve is 843.96 sq. km. located in the Kodagu and Mysore districts of Karnataka, India.

Selection of sample quadrates L: A preliminary survey was conducted to collect information about infestation level. Based on the preliminary survey, it was noticed that *L. camara* populations were found high in the dry deciduous and moist deciduous forests of the reserve which comes under southern tropical moist deciduous forests (sub group 3B type 3B/C3), southern tropical dry deciduous forests (group 5, subgroup 5A/C3) of Champion and Seth's classification (1968). Based on the cover of *L. camara*, infestation levels were grouped into different categories and a stratified random sampling technique was adopted with different levels of infestations as different strata. The quadrates having 60-80and 40-60%lantana cover was categorized as highly infested and moderately infested, areas with no lantana cover were considered as non-infested area and the areas where uprooting of lantana was done two years before was considered as uprooted area. In each stratum/category, 15 quadrates of 20 m ×20 m were laid randomly in both dry deciduous and moist deciduous forests. In each main quadrate, five sub quadrates of 2×2 m in four corners of the quadrate and one at the centre were laid to assess the regeneration status (Maheswarappa and Vasudeva 2018). All the regenerates within the subquadrate were botanically identified, and grouped under the regeneration classes for further analysis (Table 1).

In each of the main quadrates, four soil samples at 0-15 cm depth and 15-30 cm depth were collected randomly and the composite sample was prepared. The composite samples were dried at room temperature and were analyzed for pH, electric conductivity (EC), percentage of organic matter and available organic carbon by adopting standard procedures. For the canopy openness, observations were recorded at five locations within the plot and then the average of this observation was used for the calculation of the percentage of canopy openness.

Table 1. Regeneration classes

Classes	Plant description
Class I	0-40 cm height
Class II	>40-100 cm height
Class III	>100 cm height and ≤ 10 cm GBH
Class IV	>100 cm height and 10-30 cm GBH

Data analysis: The observation recorded during the field inventory was used to compute density of the regenerates, Importance value index, diversity parameters such as species richness, Shannon-Wiener index and Simpson's dominance index.All the data obtained were analysed using standard formulas with Microsoft excel (Version 2019).

RESULTS AND DISCUSSION

The density of regenerates was highest in the uprooted areas followed by moderately infested areas in dry deciduous forests. In moist deciduous forests, maximum density was observed in non-infested areas followed by uprooted areas. Natural regeneration was higher in uprooted and non-infested areas implies that natural regeneration decreased with higher lantana infestation. Mechanical uprooting is helping in improving natural regeneration of tree species (Table 2). Lantana invasion resulted in decrease in the recruitment of new individuals and recruitment of young tree individuals by successfully competing for space and light reported in Australia (Gooden et al 2009). The absence of lantana encourages the recruitment of new species. The areas highly infested with lantana showed very low regenerating individuals. Invasive species will suppress the regeneration of tree species thereby affecting native biodiversity (Litton et al 2006). Reduction in new recruitment in lantana-infested areas in the present study attributed to the dense cover created by vertical stratification of Lantana may reduce the intensity or duration of light under its canopy and thus decrease the herbaceous cover (Sharma and Raghubanshi 2015). *L. camara* and its allelopathic property may help the invasionof this species into non-native ranges also. Allelochemicals are probably released into therhizosphere of soil under its canopy and neighboring environments during the decomposition process of its residues and as leachates and volatile compounds from living plant partsof *L. camara*. Allelopathy plays a crucial role in the *L. camara* invasion and formation of monospecies stands (Nagouchi and Kurniadie 2021).

Table 2. Density (stems ha^{-1}) of regenerates under different levels of infestation

Infestation levels	Dry deciduous (stems ha^{-1})	Moist deciduous (stems ha^{-1})
Highly infested	655	715
Moderately infested	660	655
Non-infested	606	845
Uprooted	1121	740
CD (p=0.05)	217*	146

The regenerates in moderately infested regions had the highest species richness and diversity in dry deciduous woods. In the moist deciduous forests, maximum species richness was reported in highly infested regions followed by non-infested areas and greater diversity was in highly infested areas followed by non-infested areas as shown by Shannon's diversity index,the factors affecting species richness and diversity vary with geographical positions (Table 3).

Stohlgren et al (1999) reported that, conditions such as soil fertility were strongly correlated with both high native diversity and high invasive species diversity, implying that species-rich systems are not necessarily less invisible than species-poor systems. Buckley et al (2007) suggests that large-scale disturbances, such as forest fires, could drastically increase invader abundance. Dogra et al (2009) also reported that the decrease in the number of species will also affect the diversity of species within the invaded areas. Gooden et al (2009) demonstrated that the invasion of forest communities by woody plant invaders, like *L. camara*, draws significant adverse effects on native plant species diversity, both in terms of species richness and composition. The results of the present study are on par with Murali and Setty (2001) where the total number of species was highest in *L. Camara* infested plots in deciduous and scrub forests, while it is lowest in evergreen forests of Biligiri Rangan Hills. Sundaram (2011) stated that Lantana may not always suppress the growth of other species, it will more likely to grow in sites with more moisture that will also be preferred by many other species. Gooden et al (2009) found that species richness, diversity, evenness and population structure were negatively affected by increasing lantana density in south-eastern Australia. But sites where lantana was removed, has resulted in increased species richness and native species recruitment indicating an active management of the site. The number of regenerates dropped across all infestation levels as regeneration classes increased that is from seedling to sapling stage. The regeneration status in both the vegetation types followed a similar trajectory in all categories, with a typical inverse J shape curve suggesting normal regeneration. When compared to other degrees of infestation, uprooted regions and non-infested areas had a larger number of regenerates. The majority of regenerates came from regeneration class I, with the least regenerates from class IV (Fig. 1 & 2). Uprooted areas recorded maximum regenerates belonging to tree species compared to all other different levels of infestation in both locations. Population structure refers to the numerical distribution of individuals of different sizes or within a population at a given moment. Lantana flowers year-round can produce numerous seeds. An increase in light intensity and soil temperature stimulates the germination of the deposited seeds of lantana and that will lead to an increase in densities of lantana stems. Lantana may limit native tree species recruitment by competition for resources and its allelopathic nature (Gooden et al 2009). In the present study, the status of regeneration followed the similar trend in all the different levels of Lantana infestation in both the vegetation types following a normal inverse J shape curve indicating a normal regeneration trend. Uprooting of lantana was done two years before beginning of our study, regeneration was quite good in uprooted areas compared to the other three levels of infestation in dry deciduous vegetation type. Even though broadcasting of bamboo seeds has been done in moist deciduous forest, highest proportion of regenerating individuals were seen in non-infested areas. But the highest percentage of individuals belonging to class I was seen in uprooted areas, compared to all other infestation levels. It clearly indicates that, uprooting of lantana is encouraging new recruits.

The health of the forest is often indicated by the size class distribution of the community of plants. A reverse J-shaped curve for the size class distribution reflects a growing population, with a large proportion of seedlings and saplings (Sathish et al 2013). Sundaram (2011) reported that the size class structure of trees and shrubs in Biligiri Rangan Hills has changed over time with an increase in Lantana abundance

Table 3. Species richness and diversity of regenerates under different levels of Lantana infestation

Levels of Infestation		Highly infested	Moderately infested	Non-infested	Lantana uprooted
Evenness index	Moist deciduous	0.05	0.05	0.06	0.04
	Dry deciduous	0.10	0.10	0.12	0.11
Simpsons index	Moist deciduous	0.08	0.20	0.11	0.28
	Dry deciduous	0.20	0.12	0.19	0.33
Shannon's diversity index	Moist deciduous	2.85	2.07	2.58	1.61
	Dry deciduous	1.95	2.43	2.07	1.56
Species Richness	Moist deciduous	41	20	26	14
	Dry deciduous	19	24	18	14

between 1997 to 2008. Lantana invasion resulted in recruitment limitations of trees. Removal of Lantana encouraged regeneration of tree as well as shrubs compared to other infestation levels. *L. camara* inhibits native plant species recruitment by allelopathic interference of seed germination, seedling growth and survivorship. Sharma and Raghubanshi (2015) reported that in the wet sclerophyll forests of south-eastern Australia, non-invaded and managed sites showed significantly more fern, herb, tree and vine species than lantana invaded sites. Managed sites had significantly more herb and shrub species than either non-invaded or invaded sites. Shrub species richness was similar between non-invaded and invaded sites.

Canopy openness: The dry deciduous forest had the largest proportion of canopy openness, accounting for 78.43%, while the moist deciduous forest had the lowest percentage of canopy openness, accounting for 72.82%. The proportion of canopy openness and Lantana infestation has a favourable relationship (Table 4).

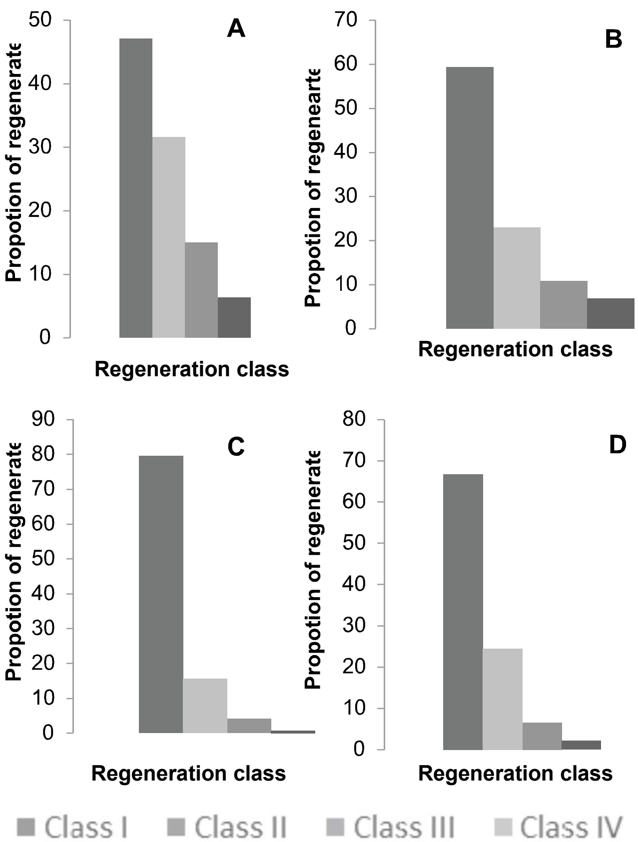

Fig. 1. Status of regeneration under different levels of infestation in dry deciduous forest (A: Highly infested, B: Moderately infested, C: Uprooted, D: Non-infested areas)

Parsons and Cuthbertson (2001) reported that Lantana showed more growth with increasing canopy openness and also the forest recovering from fire and logging was seriously affected by these invasive species. Lantana invasion increased with an increase in canopy openings and human interference (Totland et al 2005). Lantana cover is much higher in areas with low canopy cover. Chandrashekar and Swamy (2002) reported that light availability relatively enhances Lantana growth. Light has long been recognized

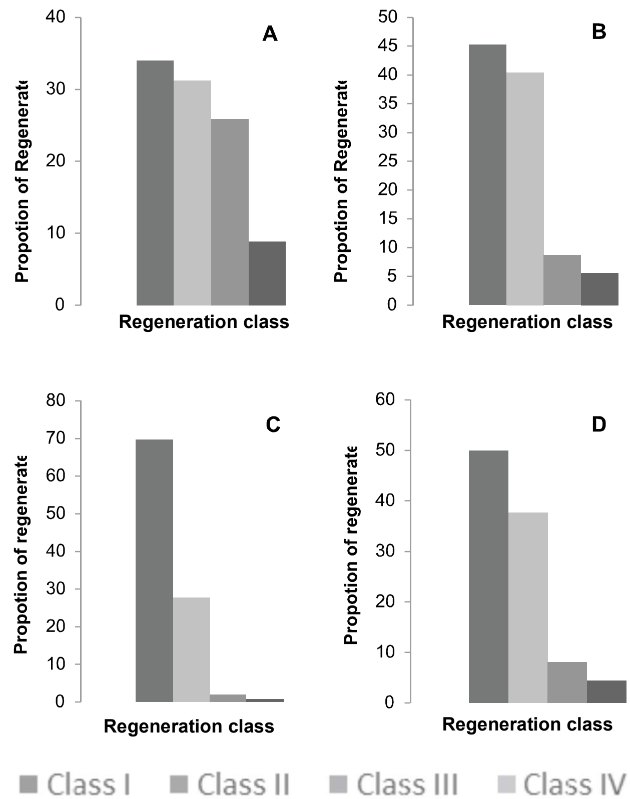

Fig. 2. Status of regeneration under different levels of infestation in moist deciduous forest (A: Highly infested, B: Moderately infested, C: Uprooted, D: Non-infested areas)

Table 4. Canopy openness (%) of dry deciduous and moist deciduous forest types

Infestation levels	Dry deciduous	Moist deciduous
Highly infested	77.70	72.82
Moderately infested	73.46	64.83
Non-infested	65.66	59.87
Uprooted	78.43	71.54
CD (p=0.05)	NS	7.771

as an important plant resource. Light availability on the forest floor has been recognized as a key factor that enhances inherent factors of inhabiting species to grow and spread. Totland et al (2005) reported that gap size and canopy openness are the factors that govern Lantana population size and reproduction. From Raizada et al (2009)study it is evident that Lantana cover was high in areas with a low native species canopy cover. Sundaram (2011) reported that canopy openness in the deciduous forest types of Biligi Rangan hills is encouraging the growth of lantana. Apart from this canopy openness, seed germination and seedling establishment rates of lantana increased with light availability and disturbance such as fire and understorey clearance. Tremendous propagule pressure, habitat heterogeneity and lantana seed sources are also playing role in enhancing the ecosystem invisibility.

Soil properties: Soil physicochemical properties varied significantly across locations as well as across different depths. The soil moisture content varied significantly among the different levels of infestation. The highest moisture content was recorded in a highly infested areas followed by a non-infested areas in both vegetation types. Sharma and Raghubanshi (2006) reported that *L. camara* biology promotes the accumulation of litter under the shrub, resulting in a buildup of organic carbon and nitrogen and can also hold water for a longer time.

Bulk density showed a significant difference across all the infestation levels. In moist deciduous forests, the non-infested area had more bulk density followed by highly infested areas, where the movement of wildlife will be high making the area more compact with less pore space. Contrasting to the expectation, in dry deciduous forest, the highly infested areas recorded more bulk density with less pore space.Debnath and Debnath (2018) observed no significant differences among invaded and non-invaded sites of *Chromolaena odorata.* The bulk densities were higher in all the three strata of *Chromolaena odorata* invaded sites of Atharamura forest of Tripura.

There was no significant difference in pH among the different vegetation types. In all the infestation levels pH was acidic ranging between 6-6.3 except for the highly infested areas of the dry deciduous forest where it had a neutral pH of 6.61-6.65. The higher soil pH was found in Lantana invaded sites compared to non-invaded sites (Osunkoya and Perrett 2010). Shackleton et al (2016) showed that the soils in Lantana invaded and uninvaded sites were generally acidic, with an average pH of 5.9 ± 0.1 in the *L. camara*-invaded sites and 5.6 in the natural sites, with no significant difference between the two sites of South Africa.

The electric conductivity varied significantly among different levels of infestation in dry deciduous forest. Highly infested as well as uprooted areas recorded the highest electric conductivity indicating high salinity in Lantana-infested areas.It indicates that, biology of Lantana will affect the soil's salinity, leading to an increase in the electric conductivity of soils. Osunkoya and Perrett (2010) also showed that no significant difference among Australia's Lantana invaded and non-invaded sites. Debnath and Debnath (2018) reported that soil conductivity was higher in both the non-invaded sites of lower and middle strata respectively while it is higher in invaded site of top strata of *Chromolaena odorata.*

The organic matter content of the soils differed significantly across locations and different infestation levels. Among different infestation levels, non-infested areas recorded the highest organic matter followed by uprooted areas. In dry deciduous forest, the highest percentage of organic matter was found in the non-infested areas followed by uprooted areas at 0-15 cm depth, whereas in 15-30 cm depth also, the maximum percentage of organic matter was observed in non-infested areas followed by uprooted areas. At 0-15 cm depth, the highest percentage of organic matter was recorded in the non-infested areas followed by uprooted areas. At 15-30 cm depth, the maximum percentage of the organic matter was recorded in the non-infested areas followed by the moderately infested areas in the moist deciduous forest. In both dry deciduous and moist deciduous forests, the non-infested areas recorded the highest percentage of organic matter.

The percentage of calculated organic carbon differed significantly across different levels of infestation in both locations. The highest organic carbon percentage was observed in the non-infested areas followed by uprooted areas. In the dry deciduous forest, the highest percentage of organic carbon was observed in the non-infested areas. Organic carbon is a derived parameter from organic matter and hence it showed a similar trend as that of organic matter (Table 5). Ehrenfeld (2003) documented both increase and decrease in organic carbon in exotic invasives. Invasives will modify soil carbon and nutrient pools but the direction and magnitude of the impacts were determined by the composition of the invasive species and soil properties. The role played by the secondary plant compounds of exotics in mediating changes in litter dynamics is completely unknown. The mechanisms causing these differences in decomposition, may include differences in size, degree and mode of vegetative spread, tissue chemistry and root distribution. The differences in litter mass or the litter decomposition rate are not always accompanied by changes in soil organic carbon dynamics.

Table 5. Soil parameters of both dry deciduous and moist deciduous forest types

Soil parameters	Infestation levels	Dry deciduous		Moist deciduous	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
Moisture content (%)	Highly infested	11.54	12.75	3.46	4.01
	Moderately infested	8.02	8.17	3.39	4.82
	Uprooted	8.11	8.69	2.84	3.15
	Non-infested	9.28	9.84	1.92	2.37
	CD (p=0.05)	2.33*	3.01*	1.26*	1.12*
Bulk density (g cc^{-1})	Highly infested	1.14	1.16	1.12	1.11
	Moderately infested	1.02	1.01	1.01	1.04
	Uprooted	0.92	0.92	1.08	1.13
	Non-infested	0.86	0.86	1.18	1.25
	CD (p=0.05)	0.13*	0.14*	0.12*	0.09*
Soil Ph	Highly infested	6.65	6.61	6.15	6.15
	Moderately infested	6.51	6.38	5.98	5.96
	Uprooted	6.46	6.57	6.03	6.21
	Non-infested	6.41	6.45	5.76	5.8
	CD (p=0.05)	0.24	0.32	0.34*	0.33
Electric conductivity (ds m^{-1})	Highly infested	0.18	0.17	0.11	0.1
	Moderately infested	0.09	0.09	0.12	0.09
	Uprooted	0.12	0.08	0.17	0.11
	Non-infested	0.1	0.1	0.14	0.13
	CD (p=0.05)	0.07*	0.05*	0.13	0.06
Organic matter (%)	Highly infested	5.15	5.06	4.46	4.4
	Moderately infested	3.7	3.12	4.52	4.52
	Uprooted	6.05	5.56	4.62	4.4
	Non-infested	6.15	5.8	4.65	4.57
	CD (p=0.05)	1.35*	1.53*	1.18	1.04
Organic carbon (%)	Highly infested	2.99	2.94	2.65	2.59
	Moderately infested	2.18	1.81	2.62	2.62
	Uprooted	3.51	3.23	2.68	2.55
	Non-infested	3.57	3.37	2.7	2.56
	CD (p=0.05)	0.78*	0.89*	0.68	0.6

*Soil properties are significant at the 0.05 level

CONCLUSION

Natural regeneration is being affected by the higher lantana infestation and uprooting is helping to improve the regeneration status. Higher canopy openings had higher lantana infestation. Maximum soil moisture content, bulk density, pH and electric conductivity were observed in highly infested areas but percentage of organic carbon and organic matter was highest in non-infested areas. The present investigation can be used as baseline data for future management of lantana with essential details about infestation of the species. Based on the present study, management plan can be made for removal of lantana through different ways in the future. Value addition of uprooted lantana can be taken up to improve the livelihood of local tribal communities. A long-term study can also be taken up to see the impacts of lantana and its removal on floristic diversity and regeneration over a time scale by establishing permanent plots.

AUTHORS CONTRIBUTION

HR Rashmitha - Involved in field data collection and data compilation. BN Sathish - Data collection, data analysis, and drafting the manuscript. D Mahesh Kumar - Helped in data collection, and writing of manuscript. C Harsha Kumar -

Provided the necessary permission for carrying out the research work and provided inputs for the manuscript. A Akshayakumari - Involved in field data collection, and data compilation.

REFERENCES

Bhatt JR, Singh JS, Singh SP, Tripathi RS and Kohli RK 2011. Invasive alien plants: An ecological appraisal for the indian subcontinent. *Cabi* **1**: 67-70.

Buckley YM, Bolker BM and Rees M 2007. Disturbance, invasion and re-invasion: managing the weed-shaped hole in disturbed ecosystems. *Ecology Letters* **10**: 809-817.

Champion HG and Seth SK 1968. A revised forest types of India. Delhi, India.

Chandrasekaran S and Swamy PS 2002. Biomass, litterfall and aboveground net primary productivity of herbaceous communities in varied ecosystems at Kodayar in the western ghats of Tamil Nadu. *Agriculture, Ecosystem and Environment* **88**: 61-71.

Dassonville N, Guillaumaud N, Piola F, Meerts P and Poly F 2011. Niche construction by the invasive Asian knotweeds (species complex *Fallopia*): impact on activity, abundance and community structure of denitrifiers and nitrifiers. *Biological Invasions* **13**: 1115-1133.

Debnath A and Debnath B 2018. Effects of the Invasive shrub, Chromolaena odorata on soil properties in the Atharamura forest ecosystem: Indian Himalayan state of Tripura, North East India. *International Journal of Plant Research and Biotechnology* **31**: 77-90.

Dogra KS, Kohli RK and Sood SK 2009. An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India. *International Journal of Biodiversity and Conservation* **1**: 4-10.

Ehrenfeld JG 2003. Effects of exotic plant invasions on soil nutrient cycling processes. *Ecosystems* **6**: 503-523.

Gooden B, French K, Turner PJ and Downey PO 2009. Impact threshold for an alien plant invader, *Lantana camara* L., on native plant communities. *Biological Conservation* **142**: 2631-2641.

Hareesh TS 2000. *Phenology, regeneration and propogation studies in Ougeinia dalbergioides Benth*. Ph.D. thesis, University of Agricultural Sciences, Dharwad, Karnataka.

Litton CM, Sandquist DR and Cordell S 2006. Effects of non-native grass invasion on aboveground carbon pools and tree population structure in a tropical dry forest of Hawaii. *Forest Ecology and Management* **231**:105-113.

Maheswarappa V and Vasudeva R 2018. Structural and floristic diversity of different landscape in Western Ghats of Kodagu, Karnataka, India. *Indian Journal of Ecology* **45**(3): 462-469.

Murali KS and Setty RS 2001. Effect of weeds *Lantana camara* and Chromelina odorata growth on the species diversity, regeneration and stem density of tree and shrub layer in BRT sanctuary. *Current Science* **80**: 675-678.

Nagouchi KH and Kurniadie D 2021. Allelopathy of *Lantana camara* as an invasive plant. *Plants* **10**: 1028.

Osunkoya OO and Perrett C 2010. *Lantana camara* L. (Verbenaceae) invasion effects on soil physicochemical properties. *Biology and Fertility of Soils* **47**: 349-355.

Parsons WT and Cuthbertson EG 2001. Noxious weeds of Australia. CSIRO, Australia.

Raizada P, Singh A and Raghubanshi AS 2009. Comparative response of seedlings of selected native dry tropical and alien invasive species to CO_2 enrichment. *Journal of Plant Ecol*ogy **2**: 69-75.

Sathish BN, Viswanath S, Kushalappa CG, Jagadish MR and Ganeshaiah KN 2013. Comparative assessment of floristic structure, diversity and regeneration status of tropical rain forests of Western Ghats of Karnataka, India. *Journal of Applied and Natural Science* **5**: 157-164.

Shackleton CM, Ruwanza S, Sinassonsanni GK, Bennett S, De lacy P, Modipa R, Mtati N, Sachikonye M and Thondhlana G 2016. Unpacking Pandora's box: Understanding and categorising ecosystem disservices for environmental management and human wellbeing. *Ecosystems* **19**: 587-600.

Sharma GP, Raghubanshi AS and Singh JS 2005. Lantana invasion: An overview. *Weed Biology and Management* **5**: 157-165.

Sharma GP and Raghubanshi AS 2006. Effect of *Lantana camara* L. cover on local depletion of tree population in the Vindhyan tropical dry deciduous forest of India. *Applied Ecology and Environmental Res*earch **5**: 109-121.

Sharma GP and Raghubanshi AS 2015. *Lantana camara* L. invasion and impact on herb layer diversity and soil properties in a dry deciduous forest of India. *Applied Ecology and Environmental Research* **9**: 253-264.

Stohlgren TJ, Binkley D, Chong GW, Kalkan MA, Schell LD, Bull KA, Otsuki Y, Newman G, Bashkin M and Son Y 1999. Exotic plant species invade hot spots of native plant diversity. *Ecological Monographs* **69**: 25-46.

Sundaram B 2011. *Patterns and processes of Lantana camara persistence in South Indian tropical dry forests*. Ph D. thesis. Manipal University, Ashoka Trust for Research in Ecology and the Environment.

Totland Q, Nyeko P, Bjerknes AL, Hegland SJ and Nielsen A 2005. Does Forest gap size affect population size, plant size, reproductive success and pollinator visitation in *Lantana camara*, a tropical invasive shrub? *Forest Ecology and Management* **215**: 329-338.

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