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Plant invasions along roads: a case study from central highlands, India

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Abstract Road sides provide suitable conditions for the establishment and growth of non-native species. The phenomenon of non-native species spread through roads has further increased due to rapid anthropogenic developments. Here we intend to investigate the status of native and non-native species and how the species richness and diversity change in a perpendicular road transect across the three different road use types in the central highlands of India. Presence of 55 non-native species was recorded, of the total 71 species along the road sides. Non-native species richness significantly increased with increasing road use type. Although, the species diversity significantly decreased from road verges to the forest interior in all the road use types. Indicating the role of non-native propagule spread through the roads into the interior forest landscapes. The study gives a management implication, to restrict the non-native species spread from the road sides to the forest interior, irrespective of road use types.

Keywords Biological invasion · Diversity · India · Non-native · Road-use

Introduction

The ongoing growth of urban agglomerations leads to far reaching changes in biodiversity, including the loss of forests and other natural areas (von der Lippe and Kowarik 2007, 2008). Under human influence, however, the rate and spatial scale of invasions has increased to unprecedented levels. The recent construction and development of roads network has further increased the fragmentation of the habitats. In developed countries the road network extends over large areas and is particularly dense in highly populated regions (Hawbaker et al. 2004). However, in developing countries the road networks are still not very strong in the rural areas especially in India. But the construction and maintenance of the golden quadrilateral, north–south and east–west corridors in India could have major impacts on landscape and ecosystem dynamics (Anonymous 2007; Hawbaker and Radeloff 2004). Such prevailing situations provide suitable conditions for the establishment, growth and spread of non-native species (Trombulak and Frissell 2000; Hansen and Clevenger 2005; Rentch et al. 2005). It is often

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suggested that roads act as corridors for the spread of invasive non-native species into new landscapes (Lonsdale and Lane 1994; Gelbard and Belnap 2003; Pauchard and Shea 2006; Kowarik and von der Lippe 2007) therefore it is likely that the density of non-natives is likely to be more around the road sides (road verges). But very few studies have shown the spatial pattern of non-natives across the roads. As roads are the important factor in the arrival and establishment of non-native species in new regions (Harrison et al. 2002). Road side areas provide habitat and also facilitate the exchange between populations and the colonization of suitable habitat (Beier and Noss 1998; Gonzalez et al. 1998), and by directing the movement of propagules to habitats with a relatively high survival probability (Wenny 2001). Understanding the mechanisms of such range expansion is a crucial prerequisite for both prevention and management of invasive non-native species (Pyšek and Hulme 2005). Amor and Stevens (1975) made the first attempt to quantify the spread of weeds from the roadside into sclerophyll forest of Dartmouth, Australia. However, still no such study from India is available in this regard. Although, Sharma et al. (2005a, b; Sharma and Raghubanshi 2006, 2007) made considerable study on plant species invasion, in the dry deciduous forests of India and observed that several noxious invasive non-native species have spread in the Central highlands, India. But the possible role of roads in promoting their spread is still unknown. Here we intend to investigate the possibility, that road side areas in the dry deciduous forest ecosystem are more dominated by non-natives. And if so, whether these non-native species richness change with the road use type and distance from the road. So, further strategies for non-native invasive species management can be designed accordingly for different road use types.

Study area

The study area lies on the Vindhyan plateau in the Sonebhadra district of Uttar Pradesh (24°13′ to 24°19′ N; 83°59′ to 83°13′ E). Due to rapid industrialization in the area the population of the area increased tremendously. In fact, during past 20-years (1981–2001), human population attained double (1,463,468) in the Sonebhadra district of the Vindhyan region (Anonymous 2003). This has led to increased use and further construction of roads (around the years 1997–2000), possibly leading to spread of non-native species.

Methods

We identified three road-use types: primary (high-use roads), secondary (low-use roads) and tertiary (seldom used or abandoned roads) in the Vindhyan dry deciduous forest ecosystem. Road-use categories were based on the subjective evaluation of the frequency of vehicle traffic. Three 0.1 km perpendicular belt transects were established in each of the road types. Each belt transect was subdivided into ten sampling units of 10 × 10 m. And four (0.5 × 0.5 m) sub plots were randomly sampled for density, frequency and cover of herbaceous species, inside each 10 × 10 m sampling units. Herbaceous layer is very sensitive to recent habitat changes due to road construction and maintenance. So for the change detection with road use type, herbaceous layer was used as an indicator (Gilliam 2007). Relative Importance Values were calculated as the sum of the mean values of relative cover, relative density and relative frequency (Curtis 1959) for each (10 × 10 m) sampling unit from the road verge to the forest interior for each road-use type. Diversity indices were calculated using the following equations:

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

(Shannon and Weaver 1949)

H' = Shannon–Wiener index, S = number of species, p_i = proportion of individuals belonging to species i, ln = natural log (i.e. base 2.718).

Results and discussion

A total of 71 species was recorded from the entire study area (Appendix). With only 16 native species and 55 non-native species, suggesting that with the increasing anthropogenic disturbance the nativity of the plant communities of the

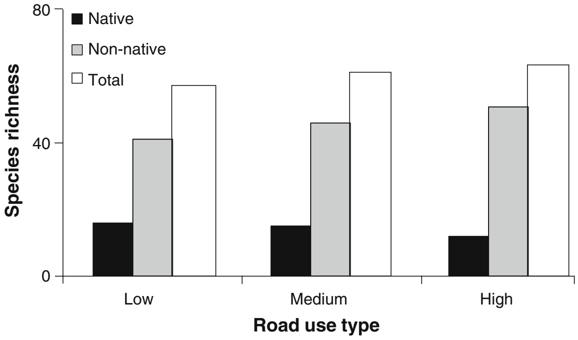

Fig. 1 Species richness of native, non-native and total species in different road use types of Central highlands, India

region is at catastrophe (Fig. 1). Higher number of herb species coincided with high non-native species richness. At smaller scale the high herb species richness were also characterized by highest number of non-native species were similar to the findings of Cantero et al. (2003) from central Argentine mountain grasslands. Thus these results do not favour the hypothesis of Elton (1958), which states, that areas of high species diversity prevent invasions (Robinson and Quinn 1988; Timmins and Williams 1991; Stohlgren et al. 1999; Cantero et al. 2003). Although most of the forest edges are highly invaded by *Lantana camara* (Raizada et al. 2008). Highly diverse communities are intrinsically unstable, with some species dropping in and out routinely (May 1973). In such a system we might envision some native species dropping out and non-native species replacing them (Stohlgren et al. 1999). Huston and DeAngelis (1994) argued theoretically that a large number of species can coexist as a result of biogenic small scale heterogeneity and interactions among organisms for spatially and temporally variable resources. Under this scenario, non-native plant species might invade and coexist with high numbers of native plant species as long as light, water and nutrients are not limiting (Stohlgren et al. 1999). These conditions appear in disturbed dry deciduous forests road verges, more often leading to the establishment of well develop non-native flora as evident from results of this study.

Significant increase in species richness was observed with increasing road use (Fig. 1). This could be attributed to the non-native species intensification with the increasing road use types. Indicating the proliferation of non-natives (some of them invasive) favored at the road verges with increasing road-use. Resulting in colonization and eventually dominance of road verges by non-natives, which often establish readily in disturbed habitats and have high seed production (Hansen and Clevenger 2005; Pauchard and Alaback 2004). Once established, populations of these non-natives may spread rapidly throughout the verge due to the verge's suitable habitat conditions (Christen and Matlack 2006). High propagule pressure from such non-native plant dominated verges may also ultimately lead to the invasion of adjacent land, and further spread of non-native plants across the landscape (Richardson et al. 2000; Von Holle and Simberloff 2005). Although there was a significant decrease in herb species diversity from the road verges to the forest interior in all the road use types ($y = -0.1658x + 22.795$, $R^2 = 0.42$; $p = 0.01$) (Fig. 2). Suggesting roads as an important source of non-native propagule bombardment at the forest edges. However, in Fig. 2, medium level of diversity at the edges of low-use road type may be explained using the intermediate disturbance hypothesis (IDH) that allows the maintenance of intermediate level of diversity in some locations of tropical forests (Connell 1978). Kadmon and Benjamini (2006) also demonstrated this through a neutral model of

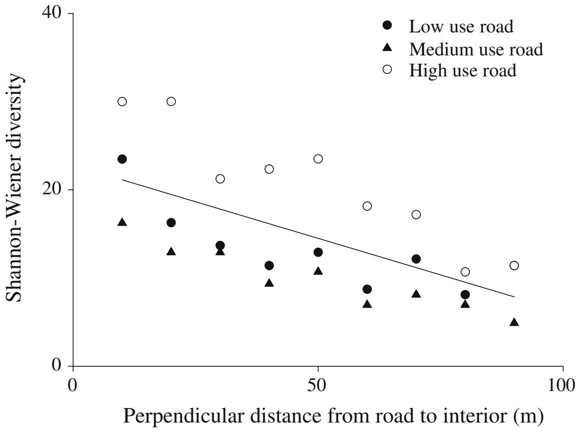

Fig. 2 Relationship between Shannon–Wiener diversity from the road verges to the forest interior in all the road use types ($y = -0.168x + 22.795$, $R^2 = 0.42$; $p < 0.01$)

species, and suggested that some level of disturbance induced diversity. The role of road verges as either habitat reserve or invasion reservoir and corridor is likely to be ecosystem and management dependent (Von Holle and Simberloff 2005), and this need to be further investigated.

Native species richness ($R^2 = 0.98$; $p = 0.01$) and relative importance value indices ($R^2 = 0.96$; $p = 0.01$) increased with increasing perpendicular distance from the road verge (Fig. 3a, b). Opposite trend was observed for non-native species respectively ($R^2 = 0.98$; $p = 0.01$, $R^2 = 0.97$; $p = 0.01$) (Fig. 3a, b). Non-native plants have been shown to decline in cover or density with increasing distance from the road (Flory and Clay 2006; Hansen and Clevenger 2005). Such decline could indicate an ongoing process of non-native plants dispersing into the adjacent land (Gelbard and Harrison 2003). Altered habitat conditions and propagule pressure from various sources can cause road verges to become colonized by non-native species (Gelbard and Belnap 2003).

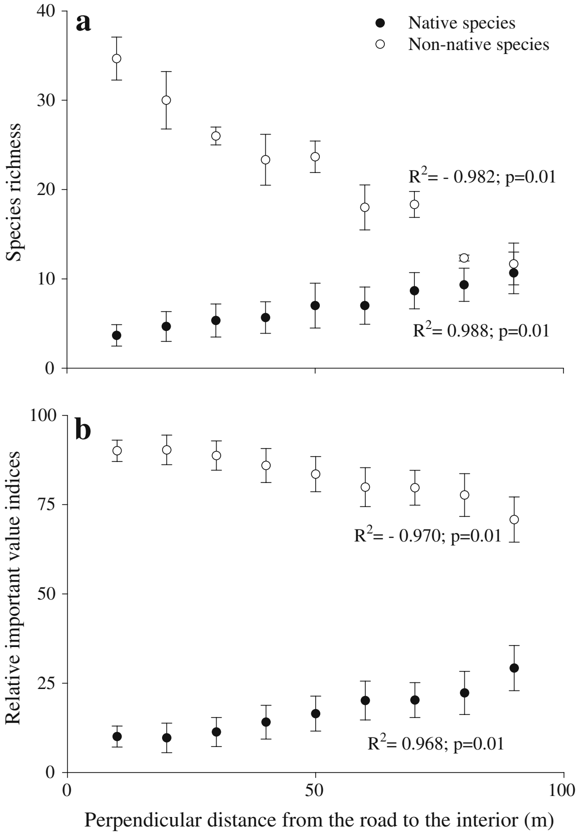

Fig. 3 Relationship between species richness (**a**) and relative importance value indices (**b**) for native and non-native species from the road verges to the forest interior of Central highlands, India (mean values of all road-use type represented)

The spatial relationship between road use types and non-native species richness suggests that vehicular use were the important sources from which non-native plant propagules had escaped possibly (Arévalo et al. 2005; Pauchard and Alaback 2004). Once established, non-native species population is unlikely to disappear from a road sides due to the combination of a persistent seed bank, regular bombardment of non-native propagules and ongoing anthropogenic disturbance that favours the establishment and persistence of non-native species (Milton and Dean 1998; Milton 2004).

Conclusions

The results suggest that the non-native species enhance the physical displacement of native species, resulting in native biodiversity loss and devastating effects on survival of endangered species with limited ranges, with varying road-use types. According to Singh et al. (2002) many native species were used by the local tribes for medicinal purposes. But this knowledge could be ruined if the non-native flora takes over the native flora. So, proper management is needed to conserve the native herbaceous diversity of the region. And this can only be achieved when road management companies and the forest department work in hand with each other. As road ecology is one of the great frontiers awaiting science and society for the betterment of humans.

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Appendix

Table 1 Importance value indices (ivi) of herbaceous species in three road use types

	n/nn	Road use type																										
		Low									Medium									High								
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Alysicarpus vaginalis (L.) DC	n	–	0.6	–	–	–	–	–	–	7.2	–	–	1.8	0.9	2.4	–	0.3	–	0.6	–	–	–	1.4	2.8	–	–	1.4	2.1
Ampelocissus latifolia Planch.	n	–	2.7	–	–	–	–	–	0.9	–	–	1.1	2.1	3.4	2.5	0.7	1.4	1.5	2	1.7	–	1.5	1.8	1.6	–	1.9	1.5	2
Andrographis echioides Nees.	n	–	–	–	–	–	–	0.9	–	–	–	–	–	–	–	–	–	–	–	2.7	0.9	2.5	–	–	1.4	3.3	3.7	1.6
Barleria cristata L.	n	–	–	–	–	–	–	–	–	–	2.4	–	2.1	–	1.4	–	–	1.8	–	–	–	1.7	1.5		3	–	0.6	0.8
Begonia picta Sm.	n	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.8	0.1	6.1	–	–	–	–	1.9	0.7	1.7	–	–
Ceropegia bulbosa Roxb.	n	–	–	–	–	–	–	–	–	–	–	–	–	–	1.1	–	–	–	–	–	–	–	2.1	0.5	–	–	1.1	5.1
Chloris dolichostachya Lag.	n	–	–	–	–	6.3	–	–	–		–	–	–	–	–	–	1	–	–	2.6	2.1	–	–	2.3	3.7	1.3	–	1
Crotalaria albida Heyne ex Roth	n	1.8	–	5.1	–	–	2.8	10	1.6	4.6	2.4	1.9	–	–	–	1.4	0.8	0.1	1.3	1.9	2.1	0.8	–	–	2.9	1.9	2.9	1.7
Crotalaria prostrata Rottl. ex Willd.	n	–	–	1.7	3.8	–	2.3	–	0.5	1.9	–	4.5	0.8	–	–	3.8	0.6	–	–	–	0.9	0.8	1.9	2	–	1.4	6	1.1
Cyanotis axillaris Schult.	n	5.6	0.5	1	1.9	5.4	19	2.6	8.6	3.5	2	–	–	0.9	1.1	0.5	1.1	1.4	1.4	4.2	6.2	1.3	1.5	0.7	1.8	2.6	1.1	6.3
Habenaria commolinifolia L.	n	–	–	–	–	–	–	2.3	–	0.6	–	–	–	–	–	–	–	3.8	0.9	2.7	3.4	–	1.6	4	4.2	–	7.3	2.2
Justicia simplex Don.	n	–	–	–	–	0.7	–	–	5.6	–	–	–	–	–	–	–	–	0.3	0.6	–	–	–	–	1.3	2.7	2	–	2.7
Leucas biflora R.Br.	n	–	–	–	–	–	–	–	–	–	–	–	–	0.5	–	–	–	–	1.1	–	–	5.4	1.8	6.4	2.8	5.2	0.9	1.9
Lindernia ciliata Pennell.	n	–	–	–	–	3.3	–	–	–	–	–	–	–	–	–	0.6	2.5	1.7	6	–	–	4.7	–	–	–	0.7	1.3	2.7
*Mukia maderaspatana*L.	n	–	–	–	7.2	–	0.7	–	1.1	4.7	–	–	–	0.8	–	–	2.1	–	0.9	–	0.9	–	–	0.5	1.5	0.1	1.8	2.3
Rungia pectinata Nees.	n	–	–	–	–	–	–	9.6	6.9	2.7	–	–	–	–	–	2.2	–	–	–	–	1.2	0.7	9.3	1.3	1.7	2.3	1.5	8.1
Adiantum sps.	nn	–	–	–	–	–	–	–	–	–	–	5.7	–	–	–	–	–	–	2.9	0.4	–	3.2	–	–	–	–	–	–
Barleria prionitis L.	nn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.3	–	–	–	0.8	–	–	–	–
Biophytum sensitivum DC	nn	–	–	–	–	–	–	–	–	–	0.7	3	3.3	8.6	3.1	2.1	3.8	–	3.5	–	–	–	3.7	4.3	–	3.5	–	–
Borreria articularis Will	nn	5.4	4.8	2.1	1.5	–	–	–	2.3	11	6.3	7	2.2	5.1	4	3.1	–	–	1.4	0.5	0.7	1.5		2.2	2.3	–	–	–
Borreria pusilla DC	nn	3	3.9	3.1	0.4	0.9	–	2.4	5.3	–	1.4	1.8	5.1	3.4	1.9	–	2.4	–	1.1	5.4	–	–	1.6	0.9	0.9	2.1	5.7	–
Canscora diffusa Vahl.	nn	3.2	–	0.4	1	1.9	–	2	–	–	2.8	0.5	0.9	1.5	–	–	–	–	9.8	0.5	0.2	–	1.4	–	2	–	6.7	–
Cassia mimosoides L.	nn	–	–	–	–	–	–	–	–	–	1.1	–	0.4	–	–	0.8	–	–	–	–	0.6	–	–	2.5	–	–	–	–
Cassia tora L.	nn	–	3.8	2.5	–	–	–	–	–		3.8	–	–	6.3	5.7	–	–	–	–	1.3	1.5	4.4	–	8	–	–	–	–
Chrysopogon fulvus Chiov.	nn	0.9	–	1.3	–	1.9	–	–	–	12	–	–	–	–	–	–	–	–	–	–	0.6	4.4	–	–	3.6	–	–	9.6
Cissampelos pareira L.	nn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.8	–	–	–	–	–	–	–	–	–	–	–
Commelina cristata L.	nn	–	–	–	–	–	0.5	–	–	–	–	–	–	–	1.1	–	–	–	–	–	–	–	–	–	–	–	–	–
Corchorus trilocularis L.	nn	–	–	–	–	–	–	1	–	–	0.3	–	–	–	–	–	–	–	–	0.3	–	–	–	–	–	7.8	–	–
Curculigo orchioides Gaertn.	nn	0.6	3.2	1.8	2.6	1	5.2	5.1	–	13	1.8	4.1	4.7	–	–	3.6	10	11	1.3	0.5	0.2	0.7	–	–	2.8	–	–	–
Cyperus cyperoides Kuntze.	nn	2.8	–	8.1	–	–	–	–	–	–	–	0.5	–	–	–	–	–	–	–	0.4	4.1	1.4	0.4	–	–	8.5	–	–
Desmodium gangeticum DC.	nn	1.1	–	–	–	–	–	–	–	–	0.8	–	0.7	1.5	–	2.1	1.7	–	–	–	–	–	1	0.8	–	–	–	5.2
Desmodium triflorum DC.	nn	2.6	2.8	6.6	0.4	0.9	5.6	–	–	–	4.7	1.1	0.4	5.3	1.8	–	4.3	–	–	2.9	1.2	–	3.6	4.5	1.8	3.4	–	–
Dichanthium annulatum Stapf	nn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3.3	–	1.1	0.7	–	–	–	2.8	–	–
Dioscorea bulbifera Voigt.	nn	–	–	–	–	–	–	–	–	–	–	2	0.7	–	–	–	1.1	–	–	–	–	5.3	1.3	–	–	–	–	3.6
Dryopteris sps.	nn	3.1	–	1.1	2	4	–	–	3.4	2.6	4.2	8.1	11	2.2	–	–	9.5	1	5.1	2.3	1.9	–	1.1	–	2.9	0.8	–	
Eragrostis tenella Beauv ex R. & S.	nn	–	1.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.5	0.5	–	–	–	–	–	–	–
Evolvulus alsinoides L.	nn	0.4	–	–	0.5	–	–	–	–	–	0.3	0.8	2.9	1.8	2.7	0.8	1.6	–	–	0.5	–	–	1.8	0.9	0.9	–	–	–
Elephantopus scaber L.	nn	1.6	–	–	0.7	1.4	7.8	5.1	–	–	0.7	0.8	1.2	1.4	1.9	3.4	0.1	2.4	–	1.1	–	4.1	3.8	–	0.7	2.2	–	–
Evolvulus nummularius L.	nn	6.9	9	3	2.3	2	15	12	–	3.6	8.6	4	9.4	16	11	7.3	–	–	–	6.5	2.5	0.7	6.9	14	1.2	6.3	–	–
Fimbristylis ferruginea Vahl	nn	–	–	–	–	–	–	–	–	–	1.1	3.2	–	–	–	3	–	–	–	–	1.9	1.4	–	1.7	–	–	–	–
Hemidesmus indicus Br.	nn	–	–	–	–	–	–	–	–	–	0.8	–	–	–	–	–	–	2.4	–	–	–	–	–	–	–	1.4	–	3.3
Hibiscus lobatus Ktze.	nn	–	0.9	0.4	–	–	1.1	–	–	–	1.2	0.4	–	–	1.2	–	–	–	–	–	0.5	–	–	1.5	–	–	–	–
Hyptis suaveolens (L.) Poit.	nn	8.7	9.1	15	–	5.6	–	1	1.9	6.2	3.3	–	3.3	4.5	3.4	–	–	–	–	6	1	5.7	5.7	–	8.6	5.7	8.7	
Ichnocarpus frutescens (L.) R. Br.	nn	3.9	0.9	1.4	2.3	1.9	2.4	–	1.9	–	4.2	1.5	4.1	3.1	1.1	5.8	6.7	5.4	5.6	1	0.3	1.3	5.2	2.3	7.5	–	2.7	3
Imperata cylindrica L.	nn	0.6	2.7	–	–	–	–	–	–	–	0.7	–	–	5.6	–	–	–	–	–	0.9	1.9	2.9	–	2.1	–	–	–	–

Table 1 (continued)

	n/nn	Road use type																										
		Low									Medium									High								
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Ipomea eriocarpa Br.	nn	0.5	0.9	1.5	1.1	1.8	–	–	–	–	0.3	–	–	–	–	–	1.6	–	–	1.4	2.6	1.9	0.8	–	–	1.6	5.5	4.5
Leucas aspera Willd.	nn	3.9	–	0.8	2.5	–	–	–	–	19	0.3	4.8	3	–	6	–	4	–	–	1.4	2.9	1	1.7	1.1	1.6	–	–	2.2
Lygodium sps	nn	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	0.4	0.3	0.7	1.4	2.8	0.9	–	–	–
Lobelia alsinoides Lamk.	nn	3.6	9.3	–	–	7.3	–	–	2	–	3.3	2.8	1.4	9.7	10	0	2.9	2.4	–	2.9	2.4	–	3	5.6	2.7	–	5.7	–
Marsdenia tenacissima W. &A.	nn	–	–	–	–	1.4	–	–	–	–	–	–	0.7	–	–	–	–	–	–	–	–	5.3	0.7	–	–	8.4	–	1.8
Melochia corchorifolia L.	nn	0.2	5	5.5	–	–	0.6	1	–	–	1.5	–	–	1.5	0.6	–	–	–	–	1.4	1.3	–	0.3	2.3	–	0.6	–	–
Mollugo nudicaulis Lamrk.	nn	–	–	–	–	–	–	–	–	–	2.3	5.6	–	–	–	–	1.2	2.4	6.2	–	–	–	–	–	–	–	–	–
Oldenlandia biflora Lamk.	nn	2.1	–	–	–	–	–	–	–	–	1.8	2.1	0.8	2.1	1.7	–	–	–	5.4	–	–	–	–	1.3	–	–	–	–
Oplismenus compositus Beaub.	nn	12	4.1	10	11	12	20	25	2.3	–	9.4	11	13	–	1.9	34	24	35	23	16	4.2	6.1	11	2.1	4.5	5.5	8.4	5
Paspalidium flavidum Camus.	nn	0.7	–	–	–	2.8	–	–	–	–	–	–	–	–	–	–	–	–	–	0.4	5.9	2.5	0.4	–	–	0.8	–	–
Phaseolus mungo Roxb.	nn	2	–	1.3	7.8	0.9	1.7	3.1	3.5	7.2	0.9	1.3	0.5	2.7	1.2	–	–	–	1.4	2	1.8	–	3.5	1.3	1.7	–	5.1	4.5
Phyllanthus niruri L.	nn	1	8.4	3.5	9.4	14	2.3	3.6	5.7	–	6.9	2.8	8.8		8.2	8.1	8.2	7.8	1.6	8.9	7.6	4.7	3.7	–	3.7	–	3.5	–
Phyllanthus urinaria L.	nn	2.9	2.5	0.9	1.3	3.5	0.6	–	9.1	–	5.3	3.8	4.5	1.5	6.8	6.2	–	–	5.4	1.5	2	–	1.3	2.4	5.5	3.5	6.2	–
Physalis minima L.	nn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.4	–	–	–	–	–	–	–	–	–	–
Rhynchosia minima DC.	nn	1.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.8	–	–	1.3	–	–	2.4	–	–
Setaria pumila R. & S.	nn	1.2	5.9	8.3	18	–	–	1	–	–	–	–	–	–	–	–	–	–	–	0.3	0.7		4.6	5.8	5.3	–	–	–
Selaginalla sps.	nn	–	–	–	–	–	–	–	–	–	0.5	2.9	–	–	–	–	–	–	–	0.6	–	2.4	0.5	0.2	–	–	–	–
Sida acuta Burm. F.	nn	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	0.2	1.9	6.5	–	–	–	–	–	–
Sida cordifolia L.	nn	8.7	6.4	10	4.5	7.9	5.3	5.1	10	–	8.3	7.1	8.3	6.5	7.8	8.4	5	11	–	1	10	3.7	3.1	–	5.1	3.4	–	16
Sida spinosa L.	nn	6.4	1.2	1.2	16	10	–	–	27	–	0.3	1.7	1.7	–	–	–	–	–	–	6.3	9.1	0.6	–	–	5.9	4.1	4.2	–
Sporobolus diander Beauv.	nn	–	2.1	–	–	–	–	–	–	–	0.3	–	–	–	2.6	–	–	–	–	2.4	5.4	0.5	–	1.5	–	–	–	–
Tephrosea pumila Pers.	nn	–	1.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.8	–	–	–	–	–	–	–
Triumfetta pentandra Rich	nn	–	1.1	0.4	–	–	6.9	1.2	–	–	1	–	–	3.1	–	1.5	–	2.4	2.2	1	0.2	3.5	–	–	–	–	–	–
Urena lobata L.	nn	1.1	2.1	1	1.1	0.9	0.7	3.3	–	–	–	–	–	–	–	–	–	–	–	1.9	1.9	–	1.7	0.6	1.6	0.6	6.6	
Vernonia cinerea Less.	nn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.4	–	–	–	3.6	–	1.1	–	–	–	–
Zornia diphylla Pers.	nn	–	3.2	–	–	–	–	–	–	–	2	1.3	–	–	5.7	–	–	–	–	0.2	0.2	–	–	–	–	–	–	–

Also given are the species native and non-native information [compiled from Jackson (1895) and personnel communication with Dr. U Dhar]

n native, *nn* non-native, Q represents ivi from road sides$_{(Q1)}$ to the forest interior$_{(Q9)}$ perpendicularly

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