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Impact of invasive alien weeds on phytodiversity of Terai–Duars region of West Bengal, India

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Abstract

The article reports the investigation on the impacts of alien invasive weeds on phyto-diversity of Terai-Duars belt of West Bengal. Invasive weed-invaded and non-invaded vegetation tracts, under same ecological conditions, were sampled and compared to understand their impact on the local biodiversity. Invaded area was inhabitated by a fewer number of species, poor in species diversity, with higher concentration of dominance and poor in species richness. The study suggested further research on the impact of aggressive and invasive alien weeds on Biodiversity and ecosystem of this area.

Key words: Invasive weeds, *Mimosa invisa*, Terai-Duars, Species diversity.

IUCN has defined the invasive alien species as "an alien species which becomes established in natural in or semi-natural ecosystem or habitat, is an agent of change and threatens native biological diversity" (IUCN, 2000). An alien plant also known as exotic, introduced, non-indigenous or non-native, is intentionally or accidentally introduced species from their native land to some other region. They have high dispersal and reproductive potential (Raghubanshi *et al.*, 2005) and spread aggressively over a huge area. Their aggressive growth affects biodiversity, ecological integrity of native habitat and ecosystems (Boot *et al.*, 2003) and can permanently alter the community structure (Carlton, 2003). Alien species are considered to be the second worst threat to the biological diversity.

Terai-Duars belt of West Bengal is contiguous with the Darjeeling Himalaya which in turn is a part of the *Himalaya Hotspot* for Biodiversity conservation that is also to house vegetation formations which are highly rich in floristic components (Rai & Das, 2008; Das & Ghosh, 2011). A number of exotic and alien weeds have been reported from Darjeeling Himalaya (Das, 2002; Ghosh, 2006; Moktan & Das, 2013). *Parthenium hysterophorus* L., *Lantana camara* L., *Mimosa invisa* Colla, *Tithonia diversifolia* (Hamsl.) A. Gray, *Ageratum houstonianum* Mill. etc. are some of the important weeds of exotic origin and have strong aggressiveness.

Several researchers have worked on floristic and some other aspects of the biodiversity of this area (Rai & Das, 2005; Ghosh, 2006; Kadir & Das, 2007; Sarkar *et al.*, 2009; Das et al., 2010a; Chowdhury & Das, 2013; Sarkar, 2011). Recently, Moktan and Das (2013) studied the diversity and distribution of invasive alien plants along the altitudinal gradient in Darjeeling Himalaya. But, specific data on impact of alien species on the biodiversity of this region is absent. Thus the present study attempted to measure phyto-sociological attributes of the vegetation invaded by alien invasive species along with the non-invaded vegetation and to compare them for understanding the impacts of these alien species on the phytodiversity of this region.

Study area

Terai – Duars belt of West Bengal is the Sub-Himalayan foot hill region that extends from Nepal

to Assam. Geographically, Terai region is situated between 25Ú57' 00" to 26Ú36'00" N latitude and 88Ú47'00" to 89Ú54'00" E longitude; whereas Duars is located between 26Ú16'00" to 27Ú00'00" N latitude and 88Ú04'00" to 89Ú53'00" E longitude and bordered by hilly region of Darjeeling district and Bhutan to the north and by Cooch Behar, North Dinajpur districts and Bangladesh to the south (Das *et al.*, 2010b).

The entire Terai-Duars belt consists of numerous pockets of varied microclimatic zones and that regulates the vegetation and its rich diversity in this region. But due to its vicinity to very high hills the temperature is rarely excessive. During summer the temperature varies between 28Ú – 38Ú C and in winter it falls down to 8.5° C or less. This area receives a high annual precipitation and the average annual rainfall ranges from 313 – 335 cm. This major part of this high rainfall is restricted within a period of 103 to 110 days during monsoon. Annual average maximum and minimum relative humidity of the entire Terai–Duars belt varies between 80 – 95% and 70 – 80% correspondingly (Sarkar, 2011).

Being contiguous with the Darjeeling Himalaya, this partially marshy belt of West Bengal is extremely rich in plant resources and its diverse floristic components are greatly influenced by the Himalayan elements. Different type of vegetation in this belt of dense forests and the grasslands are unique home to a large number of endemic and threatened plants (Das, 1996; Rai, 2006; Das, 2011). Forests and the vegetation of Terai-Duars region mainly are of (i) Tropical and Plain Vegetation and (ii) Subtropical vegetation. A number of Protected Areas have been recognized in this and adjoining areas also.

Methodology

For the present study Sukna, Salbari, Simulbari and adjoining areas which were invaded by invasive weeds were selected. *Parthenium hysterophorus*, *Lantana camara*, *Mimosa invisa*, *Ageratum houstonianum* and *Tithonia diversifolia* were considered to be assessed for their impact on local flora and vegetation. Side by side a patch of vegetation under same environmental conditions and not invaded by these exotic weeds were also selected for sampling. Those non-invaded areas were considered to be the native land use pattern. A total 50 quadrates of 5 × 5 m (with two 1 × 1 m quadrates within each) were laid out for shrubby species of which 25 are laid in invaded and other 25 are in non-invaded areas. A total of 100 quadrates of 1 × 1 m size (for herbaceous species as well as the seedlings of shrubby species) were studied for the assessment of the impact of exotic weeds. Methodology suggested by Misra (1968), Das and Lahiri (1997), Acharyya and Das (1998) and Ghosh (2006) were followed with some modifications. Different phytosociological parameters like Relative Density (RD), Relative Abundance (RA), Relative Frequency (RF) and Importance Value Index (IVI) of the weeds in invaded and non-invaded areas were calculated. Species Diversity Index [Shannon-Weiner Index (1963)], Species Richness [Menhinick's Index (1964)], Similarity Index [Sorensen's Index (1968)], and Concentration of dominance [Simpson Index (1949)] were also calculated to analyze the vegetation both in invaded and non-invaded areas.

Results and Discussion

In the present study from a total of 813 individuals belonging to 62 species, 61 genera and 27 families were recorded from the shrub layer of non-invaded area which was considered to be the native type of vegetation. From the herb layer of non-invaded areas, a total of 1393 individuals belonging to 87 species, 81 genera and 39 families were recorded. But in case of invaded areas, a total of 915 individuals belonging to 46 species, 46 genera and 21 families; and 1485 individuals belonging to 71 species, 66 genera and 34 families, were recorded from shrub and herb layers respectively (Fig. 1).

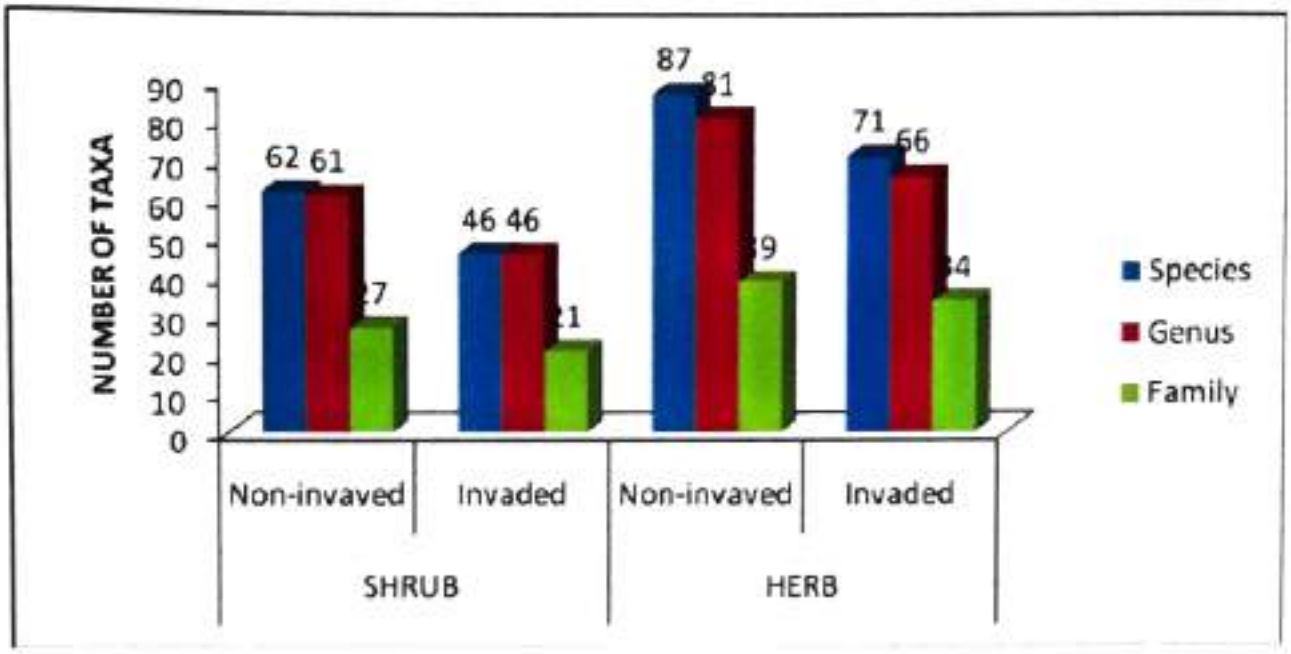

Fig. 1: Number of different taxa in non-invaded and invaded area.

Leguminosae was recorded for highest number of 9 species in invaded areas and was followed by Lamiaceae (6 spp.), Acanthaceae (3 spp.), Compositae (3 spp.), Phyllanthaceae (3 spp.) Malvaceae (3 spp.) etc. in shrub layer. In herb layer, Compositae presented highest number of 7 species and was followed by Lamiaceae (5 spp.), Leguminosae (5 spp.), Malvaceae (4 spp.) Poaceae (4 spp.) etc. In shrub layer of non-invaded areas, Leguminosae was recorded for highest number of 8 species. Other families with higher number of species were Malvaceae with 7 species, Lamiaceae with 6 species, Apocynaceae and Euphorbiaceae each with 4 species; Acanthaceae, Phyllanthaceae and Rubiaceae each with 3 species, etc. As in herb layer of invaded areas, Asteraceae was recorded for presenting maximum number of species (7 species) in case of herb layer of non-invaded areas. Other families with higher number of species were Lamiaceae (6 spp.), Leguminosae, Malvaceae and Poaceae each with 5 species, Rubiaceae (4 spp.), etc.

Picture of shrub layer

In shrub layer of non-invaded areas or control site, highest value of IVI was recorded for *Clerodendrum infortunatum* L. having index value of 29.69 along with Relative Frequency [RF] of 5.246, Relative Density [RD] of 16.851 and Relative Abundance [RA] of 7.592. Other species with high IVI score were include *Coffea benghalensis* [IVI = 25.318; RF = 4.012; RD = 13.41; RA = 7.898], *Triumfetta rhomboidea* [IVI = 20.12; RF = 4.320; RD = 10.209; RA = 5.585], *Urena lobata* [IVI = 18.21; RF = 4.32; RD = 8.98; RA = 4.91], *Mikania micrantha* [IVI=16.74; RF=5.86; RD=7.75; RA=3.12], *Tabernaemontana divaricata* [IVI = 9.14; RF= 3.70; RD= 3.32; RA= 2.12], *Marraya paniculata* [IVI= 7.56], *Dendrocnide sinuata* [IVI=7.36] (Table 1). Thus *C. benghalensis* was turned out to be the most dominant species. But, the magnitude of dominancy was not so prominent (Fig. 2) and was evident from more or less equal IVI of about 5 species. Thus it can also be inferred that the vegetation was not truly dominated by a single species but with a number of species. So, the shrub layer in non-invaded areas showed heterogeneous mixture of a number of species those play important role in the vegetation.

Table 1. Phytosociological data of shrub layer in non-invaded areas [TNI = Total number of individuals, F = Frequency, D = Density, A = Abundance, RF = Relative Frequency, RD = Relative Density, RA = Relative Abundance, IVI = Importance Value Index].

Sl No	Species	TNI	F	D	A	RF	RD	RA	IVI
1	*Clerodendrum infortunatum* L. [Lamiaceae]	137	0.68	5.48	8.06	5.25	16.85	7.59	29.69
2	*Coffea benghalensis* B. Heyne *ex* Schult. [Rubiaceae]	109	0.52	4.36	8.38	4.01	13.41	7.9	25.32
3	*Triumfetta rhomboidea* Jacq. [Malvaceae]	83	0.56	3.32	5.93	4.32	10.21	5.59	20.12
4	*Urena lobata* L. [Malvaceae]	73	0.56	2.92	5.21	4.32	8.98	4.91	18.21
5	*Mikania micrantha* Kunth [Compositae]	63	0.76	2.52	3.32	5.86	7.75	3.12	16.74
6	*Tabernaemontana divaricata* (L.) R. Br. *ex* Roem. & Schult. [Apocynaceae]	27	0.48	1.08	2.25	3.7	3.32	2.12	9.14
7	*Murraya paniculata* (L.) Jack [Rutaceae]	21	0.36	0.84	2.33	2.78	2.58	2.2	7.56
8	*Dendrocnide sinuata* (Blume) Chew. [Urtiaceae]	19	0.44	0.76	1.73	3.4	2.34	1.63	7.36
9	*Euphorbia pulcherrima* Willd. ex Klotzsch. [Euphorbiaceae]	16	0.28	0.64	2.29	2.16	1.97	2.15	6.28
10	*Morinda angustifolia* Roxb. [Rubiaceae]	14	0.24	0.56	2.33	1.85	1.72	2.2	5.77
11	*Phlogacanthus thyrsiformis* (Roxb. & Hardw.) Mabb. [Acanthaceae]	13	0.36	0.52	1.44	2.78	1.6	1.36	5.74
12	*Clausena excavata* Burm.f. [Rutaceae]	13	0.32	0.52	1.63	2.47	1.6	1.53	5.6
13	*Argyreia roxburghii* (Wall.) Arn. *ex* Choisy [Convolvulaceae]	12	0.36	0.48	1.33	2.78	1.48	1.26	5.51
14	*Croton roxburghii* Wall. [Euphorbiaceae]	11	0.4	0.44	1.1	3.09	1.35	1.04	5.48
15	*Albizia lucidior* (Steud.) I.C.Nielsen [Leguminosae]	11	0.36	0.44	1.22	2.78	1.35	1.15	5.28
16	*Mallotus philippensis* (Lam.) Müll.-Arg. [Euphorbiaceae]	9	0.32	0.36	1.13	2.47	1.11	1.06	4.64
17	*Barleria cristata* L. [Acanthaceae]	8	0.24	0.32	1.33	1.85	0.98	1.26	4.09
18	*Streblus asper* Lour. [Moraceae]	8	0.24	0.32	1.33	1.85	0.98	1.26	4.09
19	*Leea aequata* L. [Vitaceae]	7	0.28	0.28	1	2.16	0.86	0.94	3.96
20	*Sauropus compressus* Müll.-Arg. [Phyllanthaceae]	7	0.24	0.28	1.17	1.85	0.86	1.1	3.81
21	*Crotalaria alata* D. Don [Leguminosae]	7	0.16	0.28	1.75	1.23	0.86	1.65	3.74
22	*Wrightia arborea* (Dennst.) Mabb. [Apocynaceae]	7	0.2	0.28	1.4	1.54	0.86	1.32	3.72
23	*Callicarpa arborea* Roxb. [Lamiaceae]	6	0.24	0.24	1	1.85	0.74	0.94	3.53
24	*Tectona grandis* L. f. [Lamiaceae]	6	0.24	0.24	1	1.85	0.74	0.94	3.53
25	*Butea monosperma* (Lam.) Taub. [Leguminosae]	6	0.2	0.24	1.2	1.54	0.74	1.13	3.41

26	*Dalbergia sissoo* DC. [Leguminosae]	6	0.2	0.24	1.2	1.54	0.74	1.13	3.41
27	*Solanum torvum* Sw. [Solanaceae]	6	0.16	0.24	1.5	1.23	0.74	1.41	3.39
28	*Desmodium oblongum* Benth. [Leguminosae]	5	0.12	0.2	1.67	0.93	0.62	1.57	3.11
29	*Grewia asiatica* L. [Malvaceae]	5	0.12	0.2	1.67	0.93	0.62	1.57	3.11
30	*Bauhinia purpurea* L. [Leguminosae]	5	0.16	0.2	1.25	1.23	0.62	1.18	3.03
31	*Lagerstroemia speciosa* (L.) Pers. [Lythraceae]	5	0.16	0.2	1.25	1.23	0.62	1.18	3.03
32	*Maesa indica* (Roxb.) A. DC. [Primulaceae]	5	0.16	0.2	1.25	1.23	0.62	1.18	3.03
33	*Holmskioldia sanguinea* Retz. [Lamiaceae]	4	0.08	0.16	2	0.62	0.49	1.88	2.99
34	*Careya arborea* Roxb. [Lecythidaceae]	4	0.16	0.16	1	1.23	0.49	0.94	2.67
35	*Erythrina stricta* Roxb. [Leguminosae]	4	0.16	0.16	1	1.23	0.49	0.94	2.67
36	*Meyna spinosa* Roxb. *ex* Link [Rubiaceae]	4	0.12	0.16	1.33	0.93	0.49	1.26	2.67
37	*Shorea robusta* Gaertn. f. [Dipterocarpaceae]	4	0.12	0.16	1.33	0.93	0.49	1.26	2.67
38	*Sterculia villosa* Roxb. [Malvaceae]	4	0.16	0.16	1	1.23	0.49	0.94	2.67
39	*Thunbergia fragrans* Roxb. [Acanthaceae]	4	0.12	0.16	1.33	0.93	0.49	1.26	2.67
40	*Artemisia indica* Willd. [Compositae]	3	0.08	0.12	1.5	0.62	0.37	1.41	2.4
41	*Casearia glomerata* Roxb. [Salicaceae]	3	0.08	0.12	1.5	0.62	0.37	1.41	2.4
42	*Jasminum dispermum* Wall. [Oleaceae]	3	0.08	0.12	1.5	0.62	0.37	1.41	2.4
43	*Smilax orthoptera* A.DC. [Smilacaceae]	3	0.08	0.12	1.5	0.62	0.37	1.41	2.4
44	*Stephania glabra* (Roxb.) Miers [Menispermaceae]	3	0.08	0.12	1.5	0.62	0.37	1.41	2.4
45	*Tephrosia candida* (Roxb.) DC. [Leguminosae]	3	0.08	0.12	1.5	0.62	0.37	1.41	2.4
46	*Tetrastigma serrulatum* (Roxb.) Planch. [Vitaceae]	3	0.08	0.12	1.5	0.62	0.37	1.41	2.4
47	*Abroma augusta* (L.) L.f. [Malvaceae]	3	0.12	0.12	1	0.93	0.37	0.94	2.24
48	*Antidesma bunius* (L.) Spreng. [Phyllanthaceae]	3	0.12	0.12	1	0.93	0.37	0.94	2.24
49	*Bridelia glauca* Blume [Phyllanthaceae]	3	0.12	0.12	1	0.93	0.37	0.94	2.24
50	*Celastrus paniculatus* Willd. [Celastraceae]	3	0.12	0.12	1	0.93	0.37	0.94	2.24

51	*Litsea monopetala* (Roxb.) Pers. [Lauraceae]	3	0.12	0.12	1	0.93	0.37	0.94	2.24
52	*Macaranga denticulata* (Blume) Müll.-Arg. [Euphorbiaceae]	3	0.12	0.12	1	0.93	0.37	0.94	2.24
53	*Alstonia scholaris* (L.) R. Br. [Apocynaceae]	2	0.08	0.08	1	0.62	0.25	0.94	1.81
54	*Bombax ceiba* L. [Malvaceae]	2	0.08	0.08	1	0.62	0.25	0.94	1.81
55	*Buddleja asiatica* Lour. [Buddlejaceae]	2	0.08	0.08	1	0.62	0.25	0.94	1.81
56	*Dillenia pentagyna* L. [Dilleniaceae]	2	0.08	0.08	1	0.62	0.25	0.94	1.81
57	*Terminalia bellirica* (Gaertn.) Roxb. [Combretaceae]	2	0.08	0.08	1	0.62	0.25	0.94	1.81
58	*Vitex negundo* L. [Lamiaceae]	2	0.08	0.08	1	0.62	0.25	0.94	1.81
59	*Actinodaphne obovata* (Nees) Blume [Lauraceae]	1	0.04	0.04	1	0.31	0.12	0.94	1.37
60	*Maesa macrophylla* (Wall.) A. DC. [Primulaceae]	1	0.04	0.04	1	0.31	0.12	0.94	1.37
61	*Premna mollissima* Roth [Lamiaceae]	1	0.04	0.04	1	0.31	0.12	0.94	1.37
62	*Pterospermum acerifolium* (L.) Willd. [Malvaceae]	1	0.04	0.04	1	0.31	0.12	0.94	1.37

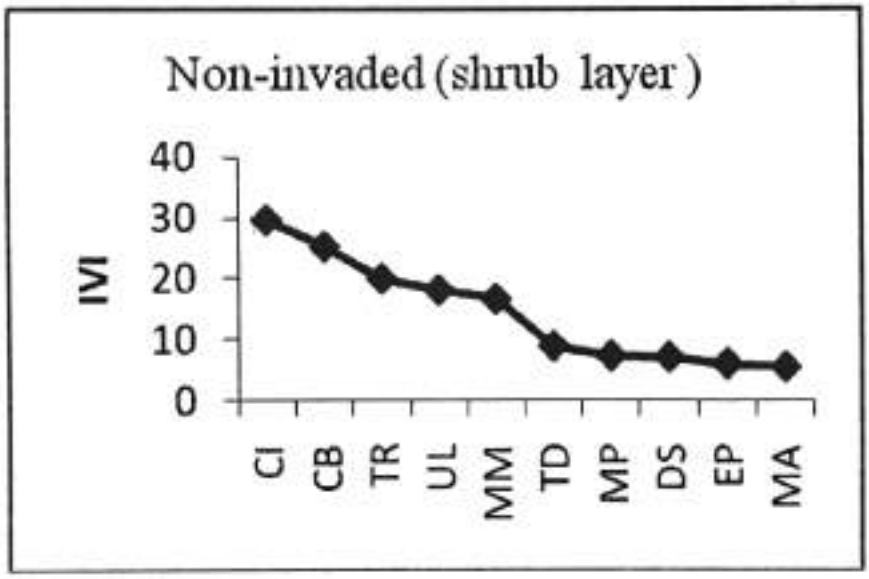

Fig. 2: IVI scores of top ten species in non-invaded shrub layer.

On the other hand, in shrub layer of invaded area highest value of IVI was recorded for *Mimosa invisa* to be 61.43 [RF = 8.71; RD = 35.74; RA = 16.97]. Other species with higher IVI score were *Lantana camara* [IVI = 28.83; RF = 5.81; RD =13.44; RA = 9.58], *Mikania micrantha* [IVI = 24.35; RF = 8.71; RD = 10.60; RA = 5.04], *Clerodendrum infortunatum* [IVI = 16.65], *Chromolaena odorata* [IVI = 13.78] *Tithonia diversifolia* [IVI = 13.52], *Coffea benghalensis* [IVI = 13.48], *Argyreia roxburghii* [IVI = 10.42], *Tabernaemontana divaricata* [IVI = 8.38] etc. Thus the vegetation was dominated by *M. invisa* and the magnitude of dominancy was much more than any other shrubby species (Fig. 3) in the vegetation as presented in Table 2. Not only that the second dominant species [*Lantana camara*] is also

a well-known invasive weed. Another aggressive weed *Tithonia diversifolia* was also on the higher side of IVI score and dominance pattern and it replaced most of the native species from their own habitat in the invaded areas.

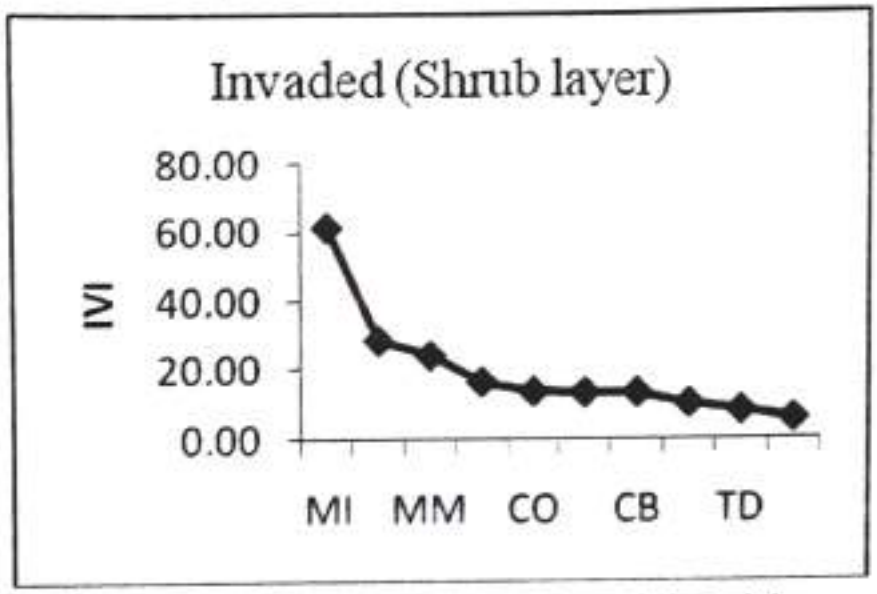

Fig. 3: IVI scores of top ten species in invaded shrub layer.

Table 2. Phytosociological data of shrub layer in invaded area.

Sl No.	Species	TNI	F	D	A	RF	RD	RA	IVI
1	*Mimosa invisa* Colla [Leguminosae]	327	0.84	13.08	15.57	8.714	35.74	16.97	61.43
2	*Lantana camara* L. [Lamiaceae]	123	0.56	4.92	8.786	5.809	13.44	9.577	28.83
3	*Mikania micrantha* Kunth [Compositae]	97	0.84	3.88	4.619	8.714	10.6	5.035	24.35
4	*Clerodendrum infortunatum* L. [Lamiaceae]	58	0.44	2.32	5.273	4.564	6.339	5.748	16.65
5	*Chromolaena odorata* (L.) R. M. King & H. Rob. [Compositae]	44	0.48	1.76	3.667	4.979	4.809	3.997	13.78
6	*Tithonia diversifolia* (Hemsl.) A. Gray [Compositae]	43	0.44	1.72	3.909	4.564	4.699	4.261	13.52
7	*Coffea benghalensis* B. Heyne *ex* Schult. [Rubiaceae]	41	0.56	1.64	2.929	5.809	4.481	3.192	13.48
8	*Argyreia roxburghii* (Wall.) Arn. *ex* Choisy [Convolvulaceae]	26	0.52	1.04	2	5.394	2.842	2.18	10.42
9	*Tabernaemontana divaricata* (L.) R. Br. *ex* Roem. & Schult. [Apocynaceae]	17	0.48	0.68	1.417	4.979	1.858	1.544	8.381
10	*Triumfetta rhomboidea* Jacq. [Malvaceae]	12	0.24	0.48	2	2.49	1.311	2.18	5.981
11	*Morinda angustifolia* Roxb. [Rubiaceae]	8	0.2	0.32	1.6	2.075	0.874	1.744	4.693
12	*Streblus asper* Lour. [Moraceae]	7	0.24	0.28	1.167	2.49	0.765	1.272	4.526
13	*Tectona grandis* L. f. [Lamiaceae]	7	0.24	0.28	1.167	2.49	0.765	1.272	4.526

14	*Desmodium oblongum* Benth. [Leguminosae]	7	0.2	0.28	1.4	2.075	0.765	1.526	4.366
15	*Urena lobata* L. [Malvaceae]	7	0.2	0.28	1.4	2.075	0.765	1.526	4.366
16	*Barleria cristata* L. [Acanthaceae]	5	0.12	0.2	1.667	1.245	0.546	1.817	3.608
17	*Callicarpa arborea* Roxb. [Lamiaceae]	5	0.16	0.2	1.25	1.66	0.546	1.363	3.569
18	*Dalbergia sissoo* DC. [Leguminosae]	5	0.16	0.2	1.25	1.66	0.546	1.363	3.569
19	*Erythrina stricta* Roxb.	5	0.16	0.2	1.25	1.66	0.546	1.363	3.569
20	*Macaranga denticulata* (Blume) Müll.-Arg.	5	0.16	0.2	1.25	1.66	0.546	1.363	3.569
21	*Bridelia glauca* Blume [Phyllanthaceae]	4	0.12	0.16	1.333	1.245	0.437	1.453	3.135
22	*Litsea monopetala* (Roxb.) Pers. [Lauraceae]	4	0.12	0.16	1.333	1.245	0.437	1.453	3.135
23	*Luffa cylindrica (L.)* M. Roem. [Cucurbitaceae]	4	0.12	0.16	1.333	1.245	0.437	1.453	3.135
24	*Wrightia arborea* (Dennsdt.) Mabb. [Apocynaceae]	4	0.12	0.16	1.333	1.245	0.437	1.453	3.135
25	*Ziziphus mauritiana* Lam. [Rhamnaceae]	4	0.12	0.16	1.333	1.245	0.437	1.453	3.135
26	*Croton roxburghii* Wall. [Euphorbiaceae]	3	0.08	0.12	1.5	0.83	0.328	1.635	2.793
27	*Butea monosperma* (Lam.) Taub. [Leguminosae]	3	0.12	0.12	1	1.245	0.328	1.09	2.663
28	*Lagerstroemia speciosa* (L.) Pers. [Lythraceae]	3	0.12	0.12	1	1.245	0.328	1.09	2.663
29	*Phlogacanthus thyrsiformis* (Roxb. & Hardw.) Mabb. [Acanthaceae]	3	0.12	0.12	1	1.245	0.328	1.09	2.663
30	*Sauropus compressus* Müll.-Arg. [Phyllanthaceae]	3	0.12	0.12	1	1.245	0.328	1.09	2.663
31	*Shorea robusta* Gaertn. f. [Dipterocarpaceae]	3	0.12	0.12	1	1.245	0.328	1.09	2.663
32	*Sterculia villosa* Roxb. [Malvaceae]	3	0.12	0.12	1	1.245	0.328	1.09	2.663
33	*Albizia lucidior* (Steud.) I. C. Nielsen [Leguminosae]	2	0.08	0.08	1	0.83	0.219	1.09	2.139
34	*Antidesma bunius* (L.) Spreng. [Phyllanthaceae]	2	0.08	0.08	1	0.83	0.219	1.09	2.139
35	*Bauhinia purpurea* L. [Leguminosae]	2	0.08	0.08	1	0.83	0.219	1.09	2.139
36	*Holmskioldia sanguinea* Retz. [Lamiaceae]	2	0.08	0.08	1	0.83	0.219	1.09	2.139
37	*Lannea coromandelica* (Houtt.) Merr. [Anacardiaceae]	2	0.08	0.08	1	0.83	0.219	1.09	2.139
38	*Maesa indica* (Roxb.) A. DC. [Primulaceae]	2	0.08	0.08	1	0.83	0.219	1.09	2.139
39	*Solanum torvum* Sw. [Slanaceae]	2	0.08	0.08	1	0.83	0.219	1.09	2.139
40	*Stephania glabra* (Roxb.) Miers	2	0.08	0.08	1	0.83	0.219	1.09	2.139

41	*Tephrosia candida* (Roxb.) DC.	2	0.08	0.08	1	0.83	0.219	1.09	2.139
42	*Trichosanthes tricuspidata* Lour. [Cucurbitaceae]	2	0.08	0.08	1	0.83	0.219	1.09	2.139
43	*Vitex negundo* L. [Vitaceae]	2	0.08	0.08	1	0.83	0.219	1.09	2.139
44	*Careya arborea* Roxb. [Lecythidaceae]	1	0.04	0.04	1	0.415	0.109	1.09	1.614
45	*Crotalaria alata* D. Don [Leguminosae]	1	0.04	0.04	1	0.415	0.109	1.09	1.614
46	*Thunbergia fragrans* Roxb. [Acanthaceae]	1	0.04	0.04	1	0.415	0.109	1.09	1.614

Picture of herb layer

In herb layer of non-invaded areas, *Ageratum conyzoides* was recorded for its highest IVI score of 13.21 along with highest relative density (RD = 6.21), RF of 1.03 and RA of 5.97. It was followed by *Chromolaena odorata* [IVI = 10.12; RF = 1.29; RD = 5.00; RA = 3.84], *Sida acuta* [IVI = 8.63; RF = 0.26; RD = 1.73; RA = 6.43], *Diplazium esculentum* [IVI = 8.15; RF = 1.80; RD = 4.1; RA = 2.25], *Clerodendrum infortunatum* [IVI = 7.85], *Mimosa pudica* [IVI = 7.44], *Lantana camara* [IVI = 7.39], etc. (Table 3).

Table 3. Phytosociological data of herb layer in non- invaded area.

Sl No	Species	TNI	F	D	A	RF	RD	RA	IVI
1	*Ageratum conyzoides* (L.) L. [Compósitae]	97	0.08	1.94	24.25	1.03	6.21	5.97	13.21
2	*Chromolaena odorata* (L.) R.M. King & H. Rob. [Compositae]	78	0.1	1.56	15.6	1.29	5	3.84	10.13
3	*Diplazium esculentum* (Retz.) Sw. [Athyriaceae]	64	0.14	1.28	9.14	1.8	4.1	2.25	8.15
4	*Mimosa pudica* L. [Leguminosae]	37	0.04	0.74	18.5	0.51	2.37	4.55	7.44
5	*Lantana camara* L. [Lamiaceae]	23	0.02	0.46	23	0.26	1.47	5.66	7.39
6	*Triumfetta rhomboidea* Jacq. [Malvaceae]	31	0.38	0.62	1.63	4.88	1.99	0.4	7.27
7	*Spermacoce alata* Aubl. [Rubiaceae]	43	0.18	0.86	4.78	2.31	2.75	1.18	6.24
8	*Dryopteris sikkimensis* (Bedd.) Kuntze [Dryopteridaceae]	38	0.1	0.76	7.6	1.29	2.43	1.87	5.59
9	*Lygodium flexuosum* (L.) Sw. [Lygodiaceae]	33	0.06	0.66	11	0.77	2.11	2.71	5.59
10	*Oplismenus burmanni* (Retz.) P. Beauv. [Poaceae]	33	0.06	0.66	11	0.77	2.11	2.71	5.59
11	*Lepidagathis incurva* Buch.-Ham. ex D. Don [Acanthaceae]	26	0.04	0.52	13	0.51	1.67	3.2	5.38
12	*Globba racemosa* Sm. [Zingiberaceae]	8	0.36	0.16	0.44	4.63	0.51	0.11	5.25
13	*Cyanotis vaga* (Lour.) Schult. & Schult. f. [Commelinaceae]	29	0.12	0.58	4.83	1.54	1.86	1.19	4.59
14	*Ichnocarpus frutescens* (L.) W. T. Aiton [Apocynaceae]	21	0.04	0.42	10.5	0.51	1.35	2.58	4.44

15	*Amaranthus viridis* L. [Amaranthaceae]	24	0.16	0.48	3	2.06	1.54	0.74	4.33
16	*Floscopa scandens* Lour. [Commelinaceae]	9	0.28	0.18	0.64	3.6	0.58	0.16	4.33
17	*Urena lobata* L. [Malvaceae]	23	0.16	0.46	2.88	2.06	1.47	0.71	4.24
18	*Cyperus rotundus* L. [Cyperaceae]	26	0.1	0.52	5.2	1.29	1.67	1.28	4.23
19	*Senna tora* (L.) Roxb. [Leguminosae]	23	0.14	0.46	3.29	1.8	1.47	0.81	4.08
20	*Commelina diffusa* Burm.f. [Commelinaceae]	23	0.14	0.46	3.29	1.8	1.47	0.81	4.08
21	*Cyperus compressus* L. [Cyperaceae]	17	0.22	0.34	1.55	2.83	1.09	0.38	4.3
22	*Oxalis corniculata* L. [Oxalidaceae]	18	0.14	0.36	2.57	1.8	1.15	0.63	3.59
23	*Tithonia diversifolia* (Hemsl.) A. Gray [Compositae]	14	0.18	0.28	1.56	2.31	0.9	0.38	3.59
24	*Setaria palmifolia* (J. Konig) Stapf. [Poaceae]	19	0.06	0.38	6.33	0.77	1.22	1.56	3.55
25	*Amaranthus spinosus* L. [Amaranthaceae]	17	0.12	0.34	2.83	1.54	1.09	0.7	3.33
26	*Cuscuta reflexa* Roxb. [Convolvulaceae]	17	0.12	0.34	2.83	1.54	1.09	0.7	3.33
27	*Alternanthera sessilis* (L.) R. Br. *ex* DC. [Amaranthaceae]	16	0.08	0.32	4	1.03	1.02	0.98	3.04
28	*Phyllanthus urinaria* L. [Phyllanthaceae]	11	0.08	0.22	2.75	1.03	0.7	0.68	2.41
29	*Cheilocostus speciosus* (J. Koenig) C.D. Specht. [Costaceae]	9	0.06	0.18	3	0.77	0.58	0.74	2.09
30	*Euphorbia hirta* L. [Euphorbiaceae]	7	0.1	0.14	1.4	1.29	0.45	0.34	2.08
31	*Physalis minima* L. [Solanaceae]	7	0.1	0.14	1.4	1.29	0.45	0.34	2.08
32	*Merremia vitifolia* (Burm. f.) Hallier f. [Convolvulaceae]	9	0.1	0.18	1.8	1.29	0.58	0.44	2.3
33	*Solanum americanum* Mill. [Solanaceae]	9	0.1	0.18	1.8	1.29	0.58	0.44	2.3
34	*Dioscorea pentaphylla* L. [Dioscoreaceae]	8	0.04	0.16	4	0.51	0.51	0.98	2.01
35	*Hyptis suaveolens* (L.) Poit. [Lamiaceae]	4	0.06	0.08	1.33	0.77	0.26	0.33	1.36
36	*Ocimum tenuiflorum* L. [Lamiaceae]	4	0.06	0.08	1.33	0.77	0.26	0.33	1.36
37	*Mallotus philippensis* (Lam.) Müll. Arg. [Euphorbiaceae]	4	0.04	0.08	2	0.51	0.26	0.49	1.26
38	*Paederia foetida* L. [Rubiaceae]	4	0.04	0.08	2	0.51	0.26	0.49	1.26
39	*Phaulopsis imbricata* (Forssk.) Sweet [Acanthaceae]	4	0.04	0.08	2	0.51	0.26	0.49	1.26
40	*Piper betleoides* C. DC. [Piperaceae]	4	0.04	0.08	2	0.51	0.26	0.49	1.26
41	*Tetrastigma dubium* (Lawson) Planch. [Vitaceae]	4	0.04	0.08	2	0.51	0.26	0.49	1.26
42	*Naravelia zeylanica* (L.) DC. [Ranunculaceae]	3	0.06	0.06	1	0.77	0.19	0.25	1.21
43	*Morinda angustifolia* Roxb. [Rubiaceae]	3	0.02	0.06	3	0.26	0.19	0.74	1.19
44	*Curculigo orchioides* Gaertn. [Hypoxidaceae]	3	0.04	0.06	1.5	0.51	0.19	0.37	1.08
45	*Sauropus compressus* Müll.-Arg. [Phyllanthaceae]	3	0.04	0.06	1.5	0.51	0.19	0.37	1.08
46	*Thunbergia fragrans* Roxb. [Acanthaceae]	3	0.04	0.06	1.5	0.51	0.19	0.37	1.08
47	*Drymaria cordata* subsp. *diandra* (Blume) J.A.Duke [Caryophyllaceae]	5	0.06	0.1	1.67	0.77	0.32	0.41	1.5

48	*Stephania glabra* (Roxb.) Miers [Menispermaceae]	5	0.06	0.1	1.67	0.77	0.32	0.41	1.5
49	*Leea aequata* L. [Vitaceae]	1	0.02	0.02	1	0.26	0.06	0.25	0.57
50	*Pterygota alata* (Roxb.) R.Br. [Malvaceae]	1	0.02	0.02	1	0.26	0.06	0.25	0.57
51	*Natsiatum herpeticum* Buch.-Ham. ex Arn. [Icacinaceae]	12	0.02	0.24	12	0.26	0.77	2.95	3.98
52	*Dioscorea belophylla* Voigt ex Haines [Dioscoreaceae]	13	0.04	0.26	6.5	0.51	0.83	1.6	2.95
53	*Pouzolzia zeylanica* (L.) Benn. [Urticaceae]	29	0.04	0.58	14.5	0.51	1.86	3.57	5.94
54	*Anisomeles indica* (L.) Kuntze [Lamiaceae]	8	0.06	0.16	2.67	0.77	0.51	0.66	1.94
55	*Eleusine indica* (L.) Gaertn. [Poaceae]	8	0.06	0.16	2.67	0.77	0.51	0.66	1.94
56	*Sida rhombifolia* L. [Malvaceae]	8	0.06	0.16	2.67	0.77	0.51	0.66	1.94
57	*Cyanthillium cinereum* (L.) H. Rob. [Compositae]	8	0.06	0.16	2.67	0.77	0.51	0.66	1.94
58	*Dicliptera bupleuroides* Nees [Acanthaceae]	7	0.08	0.14	1.75	1.03	0.45	0.43	1.91
59	*Elephantopus scaber* L. [Compositae]	7	0.08	0.14	1.75	1.03	0.45	0.43	1.91
60	*Hypericum japonicum* Thunb. [Hypericaceae]	7	0.08	0.14	1.75	1.03	0.45	0.43	1.91
61	*Leucas zeylanica* (L.) W.T. Aiton. [Lamiaceae]	7	0.08	0.14	1.75	1.03	0.45	0.43	1.91
62	*Cynodon dactylon* (L.) Pers. [Poaceae]	31	0.14	0.62	4.43	1.8	1.99	1.09	4.88
63	*Hydrocotyle sibthorpioides* Lam. [Apiaceae]	19	0.16	0.38	2.38	2.06	1.22	0.58	3.86
64	*Clerodendrum infortunatum* L. [Lamiaceae]	61	0.14	1.22	8.71	1.8	3.91	2.14	7.85
65	*Kyllinga nemoralis* (Forst & Forst) Dandy ex Hutch. & Dalziel [Cyperaceae]	41	0.12	0.82	6.83	1.54	2.63	1.68	5.85
66	*Phyllanthus emblica* L. [Phyllanthaceae]	3	0.2	0.06	0.3	2.57	0.19	0.07	2.84
67	*Alocasia fallax* Schott [Araceae]	7	0.06	0.14	2.33	0.77	0.45	0.57	1.79
68	*Tabernaemontana divaricata* (L.) R. Br. ex Roem. & Schultes [Apocynaceae]	7	0.06	0.14	2.33	0.77	0.45	0.57	1.79
69	*Oldenlandia diffusa* (Willd.) Roxb. [Rubiaceae]	6	0.08	0.12	1.5	1.03	0.38	0.37	1.78
70	*Tinospora sinensis* (Lour.) Merr. [Menispermaceae]	6	0.08	0.12	1.5	1.03	0.38	0.37	1.78
71	*Elatostema monandrum* (Buch.-Ham. ex D. Don) H. Hara [Urticaceae]	8	0.02	0.16	8	0.26	0.51	1.97	2.74
72	*Persicaria chinensis* (L.) H. Gross [Polygonaceae]	8	0.02	0.16	8	0.26	0.51	1.97	2.74
73	*Synedrella nodiflora* (L.) Gaertn. [Compositae]	43	0.24	0.86	3.58	3.08	2.75	0.88	6.72
74	*Imperata cylindrica* (L.) Raeusch. [Poaceae]	28	0.16	0.56	3.5	2.06	1.79	0.86	4.71
75	*Typhonium trilobatum* (L.) Schott [Araceae]	13	0.06	0.26	4.33	0.77	0.83	1.07	2.67
76	*Centella asiatica* (L.) Urb. [apiaceae]	13	0.08	0.26	3.25	1.03	0.83	0.8	2.66

77	*Biophytum sensitivum* (L.) DC. [Oxalidaceae]	6	0.04	0.12	3	0.51	0.38	0.74	1.64
78	*Desmodium oblongum* Benth. [Leguminosae]	6	0.04	0.12	3	0.51	0.38	0.74	1.64
79	*Erigeron Canadensis* L. [Compositae]	6	0.04	0.12	3	0.51	0.38	0.74	1.64
80	*Ophioglossum reticulatum* L. [Ophioglossaceae]	6	0.04	0.12	3	0.51	0.38	0.74	1.64
81	*Sida acuta* Burm. f. [Malvaceae]	27	0.02	0.54	27	0.26	1.73	6.64	8.63
82	*Albizia lucidior* (Steud.) I.C. Nielsen [Leguminosae]	2	0.02	0.04	2	0.26	0.13	0.49	0.88
83	*Senna occidentalis* (L.) Link [Leguminosae]	2	0.04	0.04	1	0.51	0.13	0.25	0.89
84	*Jasminum dispermum* Wall. [Oleaceae]	2	0.04	0.04	1	0.51	0.13	0.25	0.89
85	*Litsea glutinosa* (Lour.) C.B. Rob. [Lauraceae]	2	0.02	0.04	2	0.26	0.13	0.49	0.88
86	*Momordica dioica* Roxb. ex Willd. [Cucurbitaceae]	2	0.02	0.04	2	0.26	0.13	0.49	0.88
87	*Smilax orthoptera* A.DC. [Smilacaceae]	2	0.02	0.04	2	0.26	0.13	0.49	0.88

On the other hand, in the invaded area, highest value of IVI was found for *Mimosa invisa* seedlings [IVI=24.60], which actually forms an almost continuous mat, along with RF of 6.60, RD of 14.34 and RA of 3.65. *Ageratum conyzoides*, *Chromolaena odorata* and *Clerodendrum infortunatum* together formed a group of co-dominant species having IVI scores of 16.81, 15.93 and 15.57 in respectively. But, the difference in IVI score of dominant species and co-dominant group of species was quite broad. Other species having higher IVI score were *Parthenium hysterophorus* [IVI = 10.35], *Natsiatum herpeticum* [IVI = 9.74], *Lantana camara* [IVI = 7.89], *Mimosa pudica* [IVI = 7.18], etc. (Table 4). Thus the herb layer also in invaded areas, was homogeneous type of vegetation with *Mimosa invisa* as dominant species. Dominance diversity curve of top ten species (based on IVI scores) of both non-invaded and invaded areas are presented in Figs. 4 and 5 respectively.

Table 4. Phytosociological data of herb layer in invaded area.

Sl No	Species	TNI	F	D	A	RF	RD	RA	IVI
1	*Mimosa invisa* Colla [Leguminosae]	213	0.78	4.26	5.46	6.6	14.34	3.65	24.
2	*Ageratum conyzoides* (L.) L. [Compositae]	134	0.46	2.68	5.83	3.89	9.02	3.9	16.8
3	*Chromolaena odorata* (L.) R. M. King & H. Rob. [Compositae]	117	0.68	2.34	3.44	5.75	7.88	2.3	15.9
5	*Clerodendrum infortunatum* L. [Lamiaceae]	119	0.34	2.38	7	2.88	8.01	4.68	15.5
5	*Parthenium hysterophorus* L. [Compositae]	67	0.46	1.34	2.91	3.89	4.51	1.95	10.3
6	*Natsiatum herpeticum* Buch.-Ham. ex Arn. [Icacinaceae]	13	0.02	0.26	13	0.17	0.88	8.7	9.7
7	*Lantana camara* L. [Lamiaceae]	47	0.34	0.94	2.76	2.88	3.16	1.85	7.8
8	*Mimosa pudica* L. [Leguminosae]	41	0.32	0.82	2.56	2.71	2.76	1.71	7.1
9	*Sida acuta* Burm.f. [Malvaceae]	34	0.44	0.68	1.55	3.72	2.29	1.03	7.0
10	*Senna tora* (L.) Roxb. [Leguminosae]	31	0.44	0.62	1.41	3.72	2.09	0.94	6.7

11	*Oplismenus burmanni* (Retz.) P. Beauv. [Poaceae]	33	0.38	0.66	1.74	3.21	2.22	1.1(
12	*Triumfetta rhomboidea* Jacq. [Malvaceae]	29	0.36	0.58	1.61	3.05	1.95	1.08
13	*Cyperus compressus* L. [Cyperaceae]	29	0.28	0.58	2.07	2.37	1.95	1.35
14	*Dryopteris sikkimensis* (Bedd.) Kuntze [Dryopteridaceae]	29	0.24	0.58	2.42	2.03	1.95	1.62
15	*Diplazium esculentum* (Retz.) Sw. [Athyriaceae]	27	0.2	0.54	2.7	1.69	1.82	1.81
16	*Spermacoce alata* Aubl. [Rubiaceae]	24	0.26	0.48	1.85	2.2	1.62	1.2(
17	*Urena lobata* L. [Malvaceae]	22	0.28	0.44	1.57	2.37	1.48	1.05
18	*Synedrella nodiflora* (L.) Gaertn. [Compositae]	23	0.16	0.46	2.88	1.35	1.55	1.92
19	*Imperata cylindrical* (L.) Raeusch. [Poaceae]	23	0.18	0.46	2.56	1.52	1.55	1.71
20	*Hydrocotyle sibthorpioides* Lam. [Apiaceae]	21	0.12	0.42	3.5	1.02	1.41	2.3(
21	*Kyllinga nemoralis* (J.R. Forst. & G. Forst.) Dandy ex Hutch. & Dalziel [Cyperaceae]	21	0.16	0.42	2.63	1.35	1.41	1.7(
22	*Lygodium flexuosum* (L.) Sw. [Lygodiaceae]	21	0.18	0.42	2.33	1.52	1.41	1.5(
23	*Ichnocarpus frutescens* (L.) W.T. Aiton [Apocynaceae]	16	0.26	0.32	1.23	2.2	1.08	0.82
24	*Cyanotis vaga* (Lour.) Schult. & Schult. f. [Commelinaceae]	18	0.16	0.36	2.25	1.35	1.21	1.51
25	*Tabernaemontana divaricata* (L.) R. Br. ex Roem. & Schult. [Apocynaceae]	16	0.24	0.32	1.33	2.03	1.08	0.89
26	*Commelina diffusa* Burm. f. [Commelinaceae]	17	0.18	0.34	1.89	1.52	1.14	1.2(
27	*Leucas zeylanica* (L.) W. T. Aiton. [Lamiaceae]	14	0.2	0.28	1.4	1.69	0.94	0.9(
28	*Pouzolzia zeylanica* (L.) Benn. [Urticaceae]	14	0.12	0.28	2.33	1.02	0.94	1.5(
29	*Phaulopsis imbricata* (Forssk.) Sweet [Acanthaceae]	13	0.1	0.26	2.6	0.85	0.88	1.7(
30	*Centella asiatica* (L.) Urb. [Apiaceae]	13	0.18	0.26	1.44	1.52	0.88	0.97
31	*Anisomeles indica* (L.) Kuntze [Lamiaceae]	13	0.14	0.26	1.86	1.18	0.88	1.2(
32	*Dioscorea pentaphylla* L. [Dioscoreaceae]	13	0.14	0.26	1.86	1.18	0.88	1.2(
33	*Tithonia diversifolia* (Hemsl.) A. Gray [Compositae]	12	0.18	0.24	1.33	1.52	0.81	0.89
34	*Cyperus rotundus* L. [Cyperaceae]	12	0.16	0.24	1.5	1.35	0.81	1
35	*Drymaria cordata* subsp. *diandra* (Blume) [Caryophyllaceae]	12	0.16	0.24	1.5	1.35	0.81	1
36	*Amaranthus spinosus* L. [Amaranthaceae]	11	0.16	0.22	1.38	1.35	0.74	0.92
37	*Dioscorea belophylla* Voigt ex Haines [Dioscoreaceae]	11	0.16	0.22	1.38	1.35	0.74	0.92
38	*Hyptis suaveolens* (L.) Poit. [Lamiaceae]	9	0.08	0.18	2.25	0.68	0.61	1.51
39	*Sida rhombifolia* L. [Malvaceae]	9	0.08	0.18	2.25	0.68	0.61	1.51
40	*Phyllanthus urinaria* L. [Phyllanthaceae]	9	0.1	0.18	1.8	0.85	0.61	1.2
41	*Hypericum japonicum* Thunb. [Hypericaceae]	8	0.1	0.16	1.6	0.85	0.54	1.07
42	*Alternanthera sessilis* (L.) R. Br. ex DC. [Amaranthaceae]	8	0.12	0.16	1.33	1.02	0.54	0.89
43	*Cheilocostus speciosus* (J. Koenig) C. D. Specht [Costaceae]	7	0.12	0.14	1.17	1.02	0.47	0.78
44	*Elephantopus scaber* L. [Compositae]	6	0.06	0.12	2	0.51	0.4	1.3(
45	*Morinda angustifolia* Roxb. [Rubiaceae]	7	0.1	0.14	1.4	0.85	0.47	0.9(
46	*Setaria palmifolia* (J. Koenig) Stapf [Poaceae]	6	0.06	0.12	2	0.51	0.4	1.3(
47	*Solanum americanum* Mill. [Solanaceae]	7	0.1	0.14	1.4	0.85	0.47	0.9(
48	*Senna occidentalis* (L.) Link [Leguminosae]	6	0.08	0.12	1.5	0.68	0.4	1

49	*Piper betleoides* C. DC. [Piperaceae]	6	0.08	0.12	1.5	0.68	0.4	1	2.(
50	*Cyanthillium cinereum* (L.) H.Rob. [Compositae]	6	0.08	0.12	1.5	0.68	0.4	1	2.(
51	*Merremia vitifolia* (Burm. f.) Hallier f [Convolvulaceae]	6	0.1	0.12	1.2	0.85	0.4	0.8	2.(
52	*Eleusine indica* (L.) Gaertn. [Poaceae]	4	0.04	0.08	2	0.34	0.27	1.34	1.9
53	*Jasminum dispermum* Wall. [Oleaceae]	4	0.04	0.08	2	0.34	0.27	1.34	1.9
54	*Ophioglossum reticulatum* L. [Ophioglossaceae]	4	0.04	0.08	2	0.34	0.27	1.34	1.9
55	*Globba racemosa* Sm. [Zingiberaceae]	4	0.06	0.08	1.33	0.51	0.27	0.89	1.(
56	*Momordica dioica* Roxb. *ex* Willd. [Cucurbitaceae]	4	0.06	0.08	1.33	0.51	0.27	0.89	1.(
57	*Paederia foetida* L. [Rubiaceae]	4	0.06	0.08	1.33	0.51	0.27	0.89	1.(
58	*Stephania glabra* (Roxb.) Miers [Menispermaceae]	4	0.06	0.08	1.33	0.51	0.27	0.89	1.(
59	*Tetrastigma dubium* (Lawson) Planch. [Vitaceae]	4	0.06	0.08	1.33	0.51	0.27	0.89	1.(
60	*Typhonium trilobatum* (L.) Schott [Araceae]	4	0.06	0.08	1.33	0.51	0.27	0.89	1.(
61	*Curculigo orchioides* Gaertn. [Hypoxidaceae]	2	0.02	0.04	2	0.17	0.13	1.34	1.(
62	*Leea aequata* L. [Vitaceae]	2	0.02	0.04	2	0.17	0.13	1.34	1.(
63	*Dicliptera bupleuroides* Nees [Acanthaceae]	4	0.08	0.08	1	0.68	0.27	0.67	1.(
64	*Naravelia zeylanica* (L.) DC. [Ranunculaceae]	4	0.08	0.08	1	0.68	0.27	0.67	1.(
65	*Sauropus compressus* Müll.-Arg. [Phyllanthaceae]	3	0.04	0.06	1.5	0.34	0.2	1	1.5
66	*Alocasia fallax* Schott [Araceae]	3	0.06	0.06	1	0.51	0.2	0.67	1.3
67	*Smilax orthoptera* A.DC. [Smilacaceae]	2	0.04	0.04	1	0.34	0.13	0.67	1.1
68	*Thunbergia fragrans* Roxb. [Acanthaceae]	2	0.04	0.04	1	0.34	0.13	0.67	1.1
69	*Tinospora sinensis* (Lour.) Merr. [Menispermaceae]	2	0.04	0.04	1	0.34	0.13	0.67	1.1
70	*Desmodium oblongum* Benth. [Leguminosae]	1	0.02	0.02	1	0.17	0.07	0.67	0.9
71	*Litsea glutinosa* (Lour.) C.B.Rob. [Lauraceae]	1	0.02	0.02	1	0.17	0.07	0.67	0.9

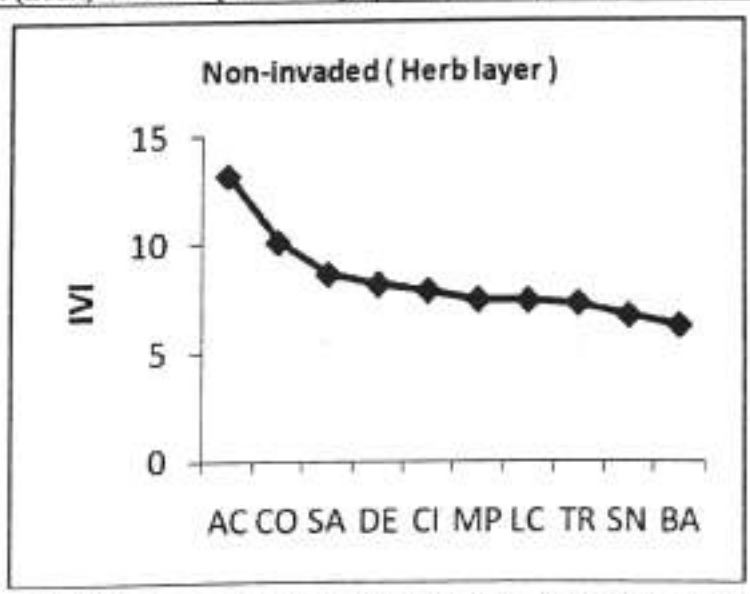

Fig. 4: IVI scores of top ten species in Non-invaded herb layer.

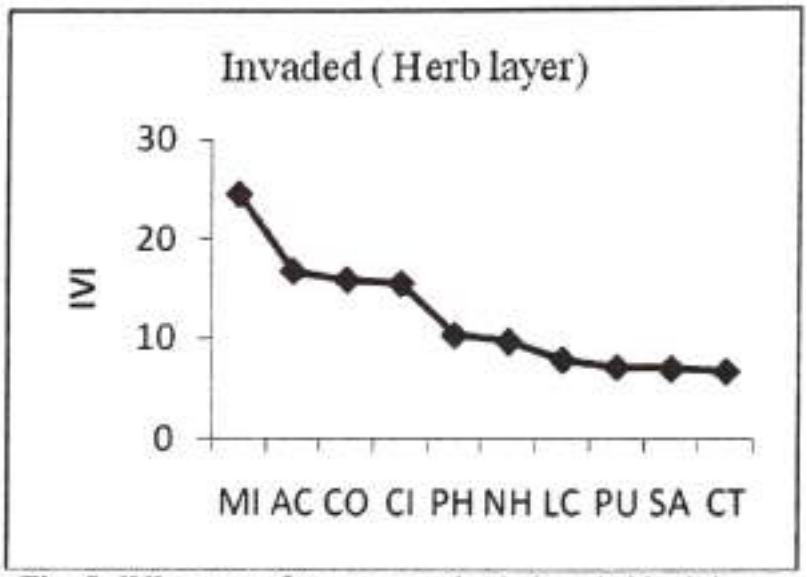

Fig. 5: IVI scores of top ten species in invaded herb layer.

Diversity indices: Species diversity index (Shannon-Weiner index) for shrub layer was calculated to -10.48 and 8.03 for invaded and non-invaded tracts of vegetation respectively. Concentrations of dominance of these 2 types of vegetation were recorded to be 67.10 and 13.14 in the same order. Thus high species diversity and lower dominance was found in non-invaded areas. Whereas the situation was just reverse in invaded areas, i.e. lower diversity and higher concentration of dominance (Fig. 6). This was further supported by lower value of Menhinick's index of species richness, MI = 0.05, for invaded areas that indicated the poor species richness in invaded area. In case of non-invaded area the species richness index was calculated to a higher value of MI = 0.076 than that of invaded area. Similarity index of Sorensen was also calculated between these two vegetation tracts to 0.70. The vegetation in both the invaded and non-invaded areas was more of less similar in respect of species composition but differ in dominance pattern and species diversity.

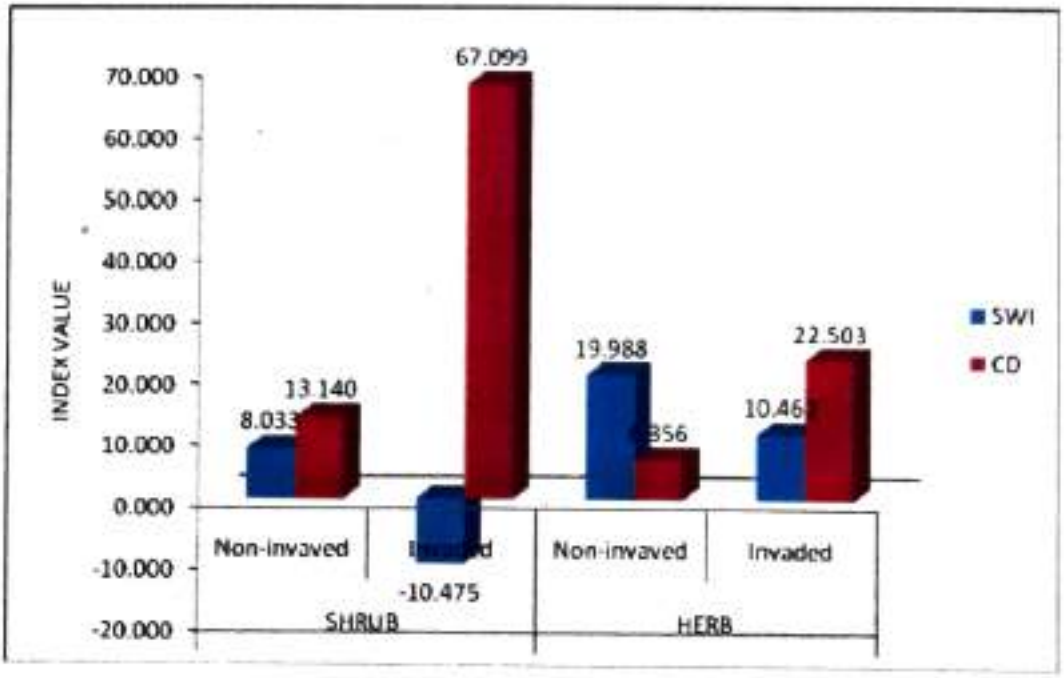

Fig. 6: Shannon-Weiner Index [SWI] and Concentration of Dominance [CD] of shrub and herb layer in innvaded and non-invaded vegetation.

For herb layer of invaded and non-invaded areas, species diversity was calculated to be 10.46 and 19.99 respectively. It indicated the less diverse vegetation of invaded areas than the non invaded one; and was further supported by the high concentration of dominance (22.50) in invaded areas than the lower value (6.36) of concentration of dominance in non-invaded site. Higher Menhinick's index value also was found in case of non-invaded areas. Similarity index of these two vegetations was found to be 0.87.

From the foregoing result it can be easily realized that the occurrences of different taxa mainly the species and genera in both shrub and herb layers of invaded area was lesser than the non-invaded areas. IVI value of different dominant species in both the shrub and herb layers of invaded area was higher than the non-invaded area and the difference in IVI values between the dominant and co-dominant species was higher in invaded area that indicated the uniformity of the vegetation in invaded site. That is further established by higher value of Simpson's index (Concentration of Dominance) and is the indication of alteration of vegetation structure in invaded area. Comparison of species richness index or Menhinick's index also indicated the species poorness of invaded area. Similar type of finding was reported by Blackburn *et al.* (2004) and Gaertner *et al.* (2009).

Conclusion

Terai-Duars region of West Bengal is well known for its diversity of flora and habitat structure and a number of invasive alien species has been naturalized and thrived over large part of area. Some other species of invasive alien weeds forms the second worst threats to the Biodiversity are rapidly colonizing in different habitat tracts in this area. This can destroy the variable and diverse ecosystem of this biodiversity rich belt and its unique flora. Further extensive research on the impact of aggressive and invasive alien weeds on Biodiversity and ecosystem of this area is highly suggested.

References

Acharyya, A. and Das, A.P. (1998). Seven new angiospermic hosts of *Orobanche aegyptiaca* Pers. (Orobanchaceae). *Bull. Bot. Surv. Indi,*. 40: 99 – 101.

Blackburn, T.M., Cassey, P., Duncan, R.P., Evans, K.L. and Gaston, K.J. (2004). Avian extinction and mammalian introductions on oceanic islands. *Science, 305*: 1955 – 1958.

Booth, B.D., Murphy, S.P. and Swanton, C.J. (2003). *Weed Ecology in Natural and Agricultural Systems*. CABI Publishing, Willingford, Oxfordshire, UK. Pp. 288.

Carlton, J.T. (2003). Community assemblage and historical biogeography in the North Atlantic Ocean: The potential role of human-mediated dispersal vectors. *Hydrobiol*, 503: 1 – 8.

Chowdhury, A. and Das, A.P. (2013). Aquatic and semi-aquatic macrophytic diversity of the river Karala at Jalpaiguri, West Bengal, India and their growth form analysis. *International Journal of Pharma and Bio Science*, 4(4): 1336 – 1343.

Das, A.P. (1996). Rediscovery of *Streptocaulon sylvestre* Wight - an endangered and little known endemic plant of Eastern India. *J. Bomb. Nat. Hist. Soc.* 93(2): 320 - 322.

Das, A.P. (2002). Survey of naturalised exotics in the flora of Darjiling Hills, West Bengal, (India). *J. Econ. Tax. Bot.* 26(1): 31 – 37.

Das, A.P. (2011). Conservation efforts for East Himalayan Biodiversity and need for the establishment of corridors. In: Ghosh, C. and Das, A.P. (eds). *Recent Studies in Biodiversity and Traditional Knowledge in India*. Sarat Book House, Kolkata, Pp. 329 – 346.

Das, A.P. and Ghosh, C. (2011). Plant wealth of Darjiling and Sikkim Himalayas *vis-à-vis* Conservation. *NBU J. Pl. Sci.* 5(1): 25 – 33.

Das, A.P. and Lahiri, A.K. (1997). Phytosociological studies of the ground

covering flora in different types of vegetation in Tiger Hill, Darjeeling District, West Bengal (India). *Indian For.* 123 (12): 1176 – 1187.

Das, A.P., Ghosh. C., Sarkar, A,, Biswas, R., Biswas, K., Chowdhury, D., Lama, A., Moktan, S. and Chowdhury. A, (2010a). Preliminary report on the Medicinal Plants from three MPCAs in Terai and Duars of West Bengal, India. *Pleione*, 4(1): 90 - 101.

Das, A.P., Samanta, A.K. and Biswas, Kishor (2010b). A census of *Piper* L. (Piperaceae) in Terai, Duars and the hills of Darjeeling and Sikkim Himalayas, *Pleione*, 4(1): 33 – 41.

Gaertner, M., Den, Bree A., Hui, C. and Richardson, D.M. (2009). Impacts of alien plant invasions on species richness in Mediterranean-type ecosystems: a meta-analysis. *Prog. in Physical Geog.* 33: 319 – 338.

Ghosh, C. (2006). Biology of tea garden weeds in Darjeeling Districts of West Bengal, India. *Ph.D. thesis. North Bengal University, West Bengal, India.*

IUCN (2000). *IUCN Guidelines for the Preservation of Biodiversity Loss caused by Alien Invasive Species*. Gland, Switzerland.

Kadir, Manzur A.F.M. and Das, A.P. (2007). Reproductive capacity and seedling survivability of *Streptocaulon sylvestre* Wight – an endangered and endemic plant of Eastern India. *Pleione*, 1(2): 62 – 68.

Menhinick, E.F. (1964). A comparison of some species- individual diversity indices applied to samples of field insects. *Ecology*, 45: 859 – 861.

Misra, R. (1968). *Ecology Workbook*. Oxford & I. B. H. Calcutta.

Moktan, S. and Das, A.P. (2013). Diversity and distribution of invasive alien plants along the altitudinal gradient in Darjiling Himalaya, India. *Pleione*, 7(2): 305 – 313.

Raghubanshi, A.S., Rai, L.C., Gaur, J.P. and Singh, J.S. (2005). Invasive Alien Species and Biodversity in India. *Curr. Sci.* 88(4): 539 – 540.

Rai, U. (2006). *Characterization of plant biodiversity in Darjiling hills using remote sensing techniques*. (Unpublished doctoral dissertation). North Bengal University, West Bengal, India.

Rai, U. and Das, A.P. (2005). Inventory of tree species in the lower hill of Darjiling district. In: Pandey, A.K., Wen, Jun. and Dogra, J.V.V. (eds). *Plant Taxonomy: Advances and Relevance*. CBS Publishers and Distributors, New Delhi, Pp. 101 – 118.

Rai, U. and Das, A.P. (2008). Diversity of Trees in the Darjiling Foothill Region of Eastern Himalaya. *NBU J. Pl. Sci.* 2: 39 – 57.

Sarkar, A., Sarkar, S. and Das, A.P. (2009). Change of vegetation structure in Gorumara National Park due to anthropogenic interferences. *NBU J. Pl. Sci.* 3: 71 – 76.

Sarkar, Ajita (2011). *Ethnobotanical Studies of Sub-Himalayan Duars in West Bengal and Assam with particular reference to the Tribe Mech*. Ph.D thesis, North Bengal University, India.

Shannon, C.E. and Winer, W. (1963). *The mathematical theory of communication*. University of Illinois Press, Urbana (Albama), Illinois.

Simpson, E.H. (1949). Measurement of Diversity. *Nature*. 163: 688.

Sorensen, T. (1968). A method of establishing group of equal amplitude in plant sociology based on similarity of species content. *Kgl. Danske Videnskab. Selskab. Biol. Skrifter* 5(4): 1 – 34.