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Phytorestoration in the debris dumping sites of a hydroelectric power project: A case study from Srinagar (Garhwal), Western Himalaya, India

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Abstract

The plant propagules migrate into denuded or conditionally created habitats by variety of means and grow, capable species establishes their population successfully and rest abolish. The present study was aimed to identify potential species in such habitats by evaluating naturalized community in conditionally crated habitats i.e. debris dumping sites of a hydroelectric power project in Western Himalayas, India for phytoretoration (eco-restoration) purpose. The data on phytosociological attributes of herbaceous community was collected from both debris dumping area (D) and undumped natural area (N) in the fringe, by quadrat method (1 x 1 m dimension). A total of 54 species from debris dumping sites and 128 species from undumped natural area (N) are recorded in this study. The invasive alien species predominates at dumping sites which covered 37% of the species richness, 50.99% of density, 76.67% of basal cover and 63.15% of dominance (IVI). Thus, invasive species are opportunistic in the process of phytorestoration in degraded habitats, which may not be beneficial for the better functioning of ecosystem but some of them can be considered as potential preliminary soil binder at such cases (dumping area). The development agencies must have an eco-restoration plan for such dumping zones which magnetized the encroachments of invasive alien species and play a pivotal role in degrading the natural ecosystem.

Key words: Dumping site, Eco-restoration, Hydroelectric power project (HEP), Invasive species, Soil binder.

Introduction

Natural or manmade factors such as erosion, floods, landslides, fire, and other anthropogenic activities denudes natural community or create fresh bare area (Walker and del Moral, 2003; Sati *et al.*, 2011). Denudation is followed by invasion, competition, stabilization and climax in the process of ecological succession. Invasion and establishment at denuded habitat by relatively competitive species is a common natural process (Wilson, 1999). It depends on the kind of ecological barriers including topography, soil conditions, available moisture content and proximate seed bank, and may prevent or restricts the establishment of ecologically favored species. As usual, the plant propagules enter in the denuded habitat by variety of means and the species capable to establish in the available habitat will colonize and the species failing to regenerate will abolish, reflecting the effect of interactions and of environmental impacts. It has been observed that the invasive species are more competitive for establishment in the denuded habitats (Bakker and Wilson, 2004). Increasing human interferences is considerable fact in the denudation of available physiography in many parts of Himalayan region (Gaur, 1999). Construction of hydroelectric projects (HEP), roads and other urbanization activities have necessarily attracted the attention in the Himalayan states, which are implemented for the sake of hydroelectric power generation, flood control, transport, infrastructure development, tourism, fisheries and many more (UJV, 2015; Agarawal, 2013). However, civil constructions related to the HEPs result into removal of huge heaps of debris, which are generally dumped over the nearby land and is treated as the dumping zones. Despite, the environmental impact assessment studies conducted before the construction of HEPs, it is rare to see that, the dumping zone has any plan for re-vegetation. Therefore, any such dumping zones

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remains affected by associated hazards and the process of re-vegetation or eco-restoration depends solely on natural process. Also, the soil gradually erodes from such dumping zones by wind and heavy rain fall. In most of the instances, the dumping zones receive negative effects due to soil erosion and nutrient loss (Kumar and Kushwaha, 2013).

Phytorestoration with rapidly growing species on proliferating debris dumping sites of HEPs can reduce habitat degradation and soil loss up to some extent. Plants and residue protects soil from raindrop impact and splash, and it also slows down the movement of surface runoff (Rey, 2003; Durán and Rodríguez, 2008) and allows excess surface water to infiltrate (Wainwright *et al.*, 2002). Plants fix soil, lower soil bulk density, increase soil organic matter and act as a physical barrier for sediment flow (Van Dijk *et al.*, 1996; Bochet *et al.*, 1998; Lee *et al.*, 2000). Commonly grasses are used to soil stabilization and re-vegetation because they grow quickly while newly planted shrubs and trees establish root systems more slowly (EPA, 2015). Plantations (tree and shrub) without understory (herbaceous layer) have no significant role in the phytorestoration of the habitats (Zhongming *et al.*, 2010). Therefore, it is very important to identify the potential herbaceous species at local level acting as a source for preliminary re-vegetation on degraded or conditionally created habitats. Considering these facts, the present study has been made to evaluate the naturally colonized plant species on debris dumping zone of Koteshwar hydroelectric power project in Western Himalayas and their comparison with proximately located natural communities.

Materials and Methods

Study area

Koteshwar or Srinagar hydroelectric power project (HEP) constructed on Alaknanda river, is located in south east direction from Srinagar city (Garhwal, Uttarakhand). Project influence area that stretches in between 30º13'44.30" – 30º14'13.70" N and 79º47'5" – 79º50'54.30" E with an elevation of 530 – 800 m asl was selected for present study (Fig. 1). This area is surrounded by many hillocks of gentle to steep slopes. Vegetation of study area is subtropical, represented by pine, pine-mixed and dry scrub forests. The summer, rainy and winter are well marked seasons in the study area and the temperature may reaches up to 40°C during summer (June). Maximum rainfall (*ca.* 70%) is received during August and September. Winter is characterized by high humidity and lowering of temperature up to 2°C.The selected area was divided in two main sites, one located near the dam construction area and another located in power house area located approximately 2.5 km apart from each other. Further, these sites were divided into four sub-sites viz. two dumping sites (D1 and D2) and two undumped natural sites (N1 and N2). The undumped natural area adjacent to the corresponding dumping sites (D1 and D2) were considered as natural sites (N1 and N2). Thus, D1 and N1 were the sites located at dam construction area while D2 and N2 were located near to the power house area. Debris excavated from HEPs work were dumped sporadically at river bank and bare lands (Fig. 2 & 3). Both of the dumping sites contained heaps of different size, covering land area of approximately from 800 m^2 to 1500 m^2, receiving dumping since last 3 – 4 years back.

Field survey and data collections

All the study sites were surveyed extensively for collection of plant specimen (herbaceous) during 2013–2016. The collected and identified plant species were processed for herbarium following standard botanical practice. Stratified random sampling method was used to sample the plant communities (herbaceous) by placing quadrats of 1 m × 1 m sized (4 sites x 70 quadrats = 280 quadrats) following Misra (1968). Stem circumference measured with the help of calipers to evaluate basal covers.

Data analysis

Collected species were identified following monographs and literatures like Herbaceous Flora of Dehradun (Babu, 1977), Flora of Chamoli (Naithani, 1984, 1985), Flora of Garhwal (Gaur, 1999) and Herbarium collections of HNB Garhwal University (GUH!). Total species count in each site was taken as the species richness. Importance value index (Curtis, 1959) and similarity index (Sorenson, 1948) were calculated for each site.

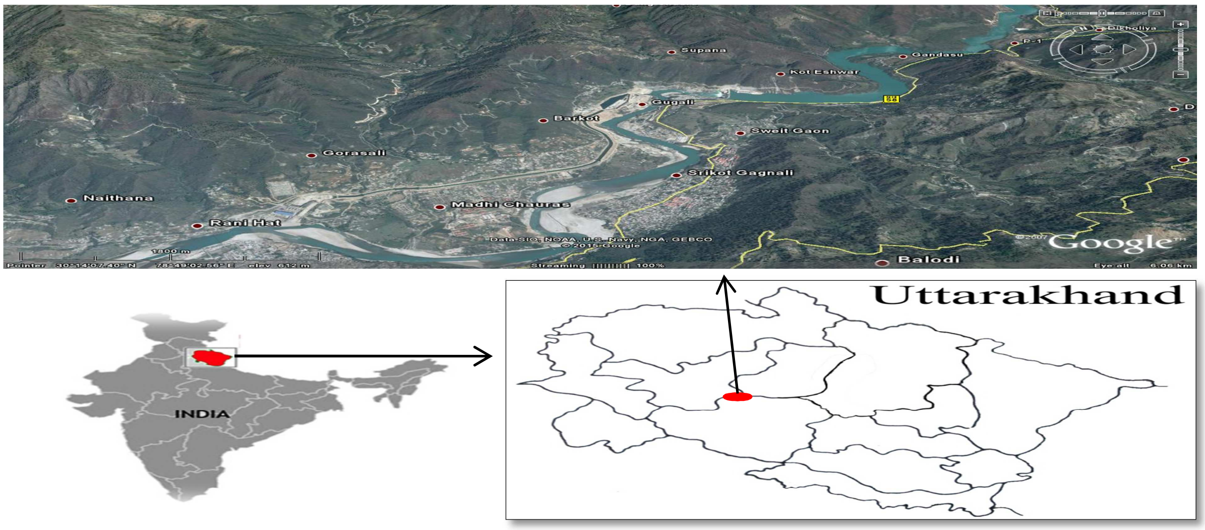

Fig. 1. Map showing study area

Fig. 2. View of one of the debris dumped at right bank of river Alaknanda which washed away during the Kedarnath tragedy (massive rain fall and cloud burst lead the flood in Alaknanda in June, 2013)

Fig. 3. Srinagar HEP workers planting on the same debris dumped site

Result and Discussion

A total of 54 species belonging to 46 genera and 22 families were recorded from the dumping sites (D1 and D2), out of which 20 species (37% of total species) were invasive alien. On the other hand, 129 species of herbaceous plants belonging to the 124 genera and 37 families were recorded from the undumped natural sites (N1 and N2), of which 19 species (14% of total species) were invasive alien. The consolidated phyto-sociological attributes of study sites are shown in Table 1. The present investigation revealed that only 37% invasive alien species together covered 50.99% of total density, 76.67% of basal cover and 63.15% of dominance (IVI) at dumping sites (D1 and D2). While, these covered 14% species richness, 26.08% total density, 37.67% of basal cover and 27.08 dominance at undumped natural area (N1 & N2). It can inferred from the finding that invasive alien species are mostly opportunistic during the re-vegetation in any denuded habitat (dumping zones). Such species are well adapted to varied environmental conditions like low nutrients and less moisture containing soils, thus are known for faster growth and biomass production compared to native species, high competitive ability, high reproductive efficiency including production of a large number of seeds, efficient dispersal, vegetative reproduction, rapid establishment and other traits that help them adapt to new habitats (Rawat *et al.*, 2016).

Table 1. Phytosociological attributes and diversity indices of the study sites.

Parameter	**Dumping sites**		**Natural sites**	
	D1	**D2**	**N1**	**N2**
Species richness	52	30	100	92
No. of genera	45	29	84	81
No. of family	21	18	28	31
Sampling units (1×1 m$^{2)}$	70	70	70	70
Density (ind. ha^{-1}),	597448	299522	882736	750909
TBC (m^2 ha^{-1})	0.86	0.84	1.69	0.94
Similarity index				
D1	1.00	–	–	–
D2	0.61	1.00	–	–
N1	0.65	0.44	1.00	–
N2	0.54	0.48	0.68	1.00

Density, basal cover and importance value index (IVI) of each species growing at dumping sites compared with their population in undumped natural area (Table 2). Among the invasive species, *Parthenium hysterophorus* showed highest density at dumping sites i.e. D1 (70750 ha^{-1}) and D2 (60000 ha^{-1}), followed by *Euphorbia hirta* (58250 ha^{-1} at D1), *Xanthium indicum* (39522 ha^{-1} at D2, 37250 ha^{-1} at D1) and *Cannabis sativa* (25000 ha^{-1} at D2). In native species at dumping sites, maximum density recorded for *Cajanus platycarpus* (128700 ha^{-1}) followed *Crotalaria medicaginea* (59700 ha^{-1}), *Cynodon dactylon* (52500 ha^{-1}), *Panicum antidotale* (31500 ha^{-1}) and *Cynodon dactylon* (25000 ha^{-1}). *Cynodon dactylon* represented maximum density at both the undumped natural sites i.e. N1 (60875 ha^{-1}) and N2 (37500 ha^{-1}) followed by *Digitaria setigera* (52875 ha^{-1} at N1), *Cannabis sativa* (50000 ha^{-1} at N1), *Micromeria biflora* (37500 ha^{-1} at N2) and others .Minimum density were recorded for *Indigofera linifolia* (430 ha^{-1}) at N1 and *Ajuga parviflora* (459 ha^{-1}) at N2.Highest basal cover (BC) represented by *Xanthium indicum* at dumping sites (28304.1 cm^2 ha^{-1}at D2, 26996.8 cm^2 ha^{-1}at D1) while minimum by *Indigofera linifolia* (25.48 cm^2 ha^{-1}) at D1and *Oxalis corniculata* (79.62 cm^2 ha^{-1}) at D2 in invasive species. Maximum BC were observed for *Ajuga bracteosa* (4305.73 cm^2 ha^{-1}) and *Crotalaria medicaginea* (3869.43 cm^2 ha^{-1}) at D1 while for *Verbascum thapsus* (9867.04 cm^2 ha^{-1}) and

Table 2. Density (ind. ha^{-1}), TBC ($cm^2\ ha^{-1}$) and IVI of recorded species at dumping sites and their comparison to natural sites.

Name of species	Dumping sites						Natural sites					
	D1			D2			N1			N2		
	DEN.	TBC	IVI	DEN.	TBC	IVI	DEN.	TBC	IVI	DEN.	TBC	IVI
Invasive alien species												
Ageratum conyzoides	4750	850.92	5.57	24500	4388.93	15.82	21250	2436.31	5.36	37500	2985.67	9.46
Alternanthera pungens	11000	165.61	4.09	-	-	-	8625	336.48	2.32	-	-	-
Bidens pilosa	1000	716.56	2.46	-	-	-	600	421.56	1.4	6250	1990.45	4.2
Cannabis sativa	10250	7344.75	19.79	25000	7961.78	20.23	50000	6727.71	10.7	18500	14154.9	14.67
Cassia occidentalis	1000	497.61	1.48	-	-	-	4375	1393.31	2.08	2500	447.85	1.8
Cassia tora	1250	168.19	1.53	2500	447.85	2.98	32000	5732.48	6.72	7000	802.55	2.53
Chenopodium album	2750	1158.24	3.27	-	-	-	9875	9088.77	9.27	2250	517.71	1.21
Chenopodium ambrosioides	2250	458.6	2.41	4000	458.6	4.3	1625	874.6	1.1	11250	2015.33	6.2
Eupatorium adenophorum	4250	571.86	2.16	8500	818.87	6.23	450	342.11	1.4	1150	756.61	3.76
Euphorbia heterophylla	1000	156.05	1.47	1000	79.62	1.23	33750	967.36	5.19	20250	403.07	5.64
Euphorbia hirta	58250	2662.62	28.29	14000	401.27	11.6	1500	190.43	1.6	1750	200.64	0.98
Indigofera linifolia	2000	25.48	1.88	-	-	-	430	140.89	0.7	-	-	-
Martynia annua	750	955.41	2.31	-	-	-	1750	737.06	1.21	-	-	-
Oxalis corniculata	3500	178.34	2.77	3500	69.67	3.67	23500	1299.36	6.39	32500	931.53	6.68
Parthenium hysterophorus	70750	23410	55.25	60000	19108.3	56.46	13875	16879	9.05	22550	2304.78	4.95
Portulaca oleracea	6250	44.79	1.58	4000	318.47	4.13	950	109.52	0.68	5000	211.51	2.1
Sida acuta	2000	192.68	1.7	-	-	-	9750	939.29	2.77	-	-	-
Solanum nigrum	1250	195.06	1.19	3000	955.41	3.75	5000	573.25	2.61	3875	694.17	2.57
Tridax procumbens	3750	191.08	2.76	3000	117.04	3.56	13125	668.79	4.06	3625	649.38	1.8
Xanthium indicum	37250	26996.8	45.17	39522	28304.1	58.12	9000	10929.9	8.59	10375	8503.18	10.96
Total	**225250**	**66940.7**	**187.13**	**192522**	**63429.9**	**192.08**	**241430**	**60788.2**	**83.2**	**186325**	**37569.3**	**79.51**
Native species												
Aerva sanguinolenta	7750	394.9	3.36	7000	557.32	4.61	560	382.72	2.4	950	711.72	3.4
Ajuga bracteosa	8000	4305.73	5.99	-	-	-	8750	4709.39	5.82	7500	3732.09	7.29
Ajuga parviflora	-	-	-	1500	1074.84	4.2	750	544.72	2.4	459	381.72	2.7
Alysicarpus bupleurifolius	2500	17.91	1.23	-	-	-	3875	308.52	1.16	-	-	-
Anisomeles indica	1500	477.71	1.92	4000	3901.27	8.39	7750	7558.72	5.64	1250	622.01	1.39

Antirrhinum orontium	1500	19.11	0.67	1500	76.43	1.4	800	94.21	0.87	1250	126.21	1.5
Artemisia japonica	-	-	-	3000	1492.83	5.2	3250	2328.82	2.18	1500	746.42	1.61
Barleria cristata	750	152.87	0.68	3500	626.99	3.53	10000	1146.5	4.03	5375	616.24	3.38
Blumea hieraciifolia	2500	127.39	2.46	-	-	-	5000	143.31	1.81	2625	252.89	1.63
Boerhavia diffusa	2500	127.39	3.09	5000	254.78	6	850	682.72	5.4	11250	438.89	5.1
Brachiaria ramose	5250	37.62	2.13	-	-	-	1150	122.65	1.3	-	-	-
Cajanus platycarpus	128700	1035.03	6.86	-	-	-	4250	54.14	1.72	-	-	-
Coix lacryma-jobi	250	9.75	0.43	-	-	-	450	11.75	0.51	-	-	-
Crotalaria medicaginea	59700	3869.43	10.5	-	-	-	4000	254.78	1.05	-	-	-
Cynodon dactylon	52500	376.19	14.28	25000	79.62	10.05	60875	436.21	12.4	37500	268.71	9.5
Cynoglossum zeylanicum	2750	140.13	2.15	3000	152.87	2.8	2000	511.32	0.98	18250	523.09	5.15
Eleocharis atropurpurea	11298	38.22	4.83	5500	39.41	7.53	1890	87.45	2.1	1550	44.21	1.6
Eragrostis atrovirens	7750	24.68	3.32	-	-	-	16375	1056.03	2.58	-	-	-
Gnaphalium hypoleucum	13500	870.62	7.55	7500	597.13	7.25	2100	765.91	1.03	26125	3515.23	7.97
Indigofera hirsuteta	4000	318.47	1.84	-	-	-	15000	1719.75	3.88	-	-	-
Launaea aspleniifolia	500	669.19	1.89	-	-	-	481	467.53	1.1	-	-	-
Panicum antidotale	31500	426.75	11.53	-	-	-	1900	544.12	1.56	-	-	-
Persicaria capitata	1000	716.56	1.72	-	-	-	800	500.12	1.9	-	-	-
Phyllanthus amarus	-	-	-	5500	109.47	6	22625	162.12	3.66	10125	290.21	2.66
Phyllanthus virgatus	2000	14.33	1.87	-	-	-	1100	1123.89	1.4	7500	95.54	1.78
Physalis micrantha	750	403.66	1.9	4000	28.66	3.79	800	511.32	1.2	-	-	-
Pupallia lappacea	1000	114.65	0.68	-	-	-	11375	443.77	3.52	2375	228.8	1.57
Rumex hastatus	-	-	-	9500	1701.83	8.42	5000	1150.48	2.13	3250	662.42	3.14
Sesbania sesban	5750	2694.86	5.77	-	-	-	-	-	-	-	-	-
Setaria glauca	5000	63.69	1.24	2500	31.85	2.49	-	-	-	1550	44.21	1.6
Sida cordata	3500	626.99	2.47	-	-	-	15750	2769.9	4.53	-	-	-
Solanum surattense	750	373.21	1.22	-	-	-	1250	99.52	0.64	1500	144.51	0.89
Themeda triandra	500	25.48	0.98	-	-	-	800	51.66	0.89	16250	207.01	3.88
Verbascum thapsus	2250	458.6	5.12	17000	9867.04	23.86	13000	7464.17	5.61	5500	5364.25	7.97
Vernonia cinerea	-	-	-	2000	101.91	2.4	-	-	-	1700	88.75	1.78
Zornia gibbosa	5000	42.99	3.66	-	-	-	21625	300.96	3.9	-	-	-
Total	**372198**	**18974.1**	**113.34**	**107000**	**20694.3**	**107.92**	**246181**	**38509.2**	**91.3**	**165334**	**19105.1**	**77.49**
Grant Total	**597448**	**85914.8**	**300.47**	**299522**	**84124.2**	**300**	**487611**	**99297.4**	**174.5**	**351659**	**56674.4**	**157**

Anisomeles indica (3901.27 cm^2 ha^{-1}) at D2 among native species at dumping sites. At N1, highest BC recorded for *Parthenium hysterophorus* (16879 cm^2 ha^{-1}) followed *Amaranthus spinosus* (1219148 cm^2 ha^{-1}) and *Amaranthus viridis* (11733.68 cm^2 ha^{-1}) whereas *Cannabis sativa* (14154.9 cm^2 ha^{-1}) represented maximum BC at N2 followed *Urtica dioica* (9554.14 cm^2 ha^{-1}) and *Xanthium indicum* (8503.18 cm^2 ha^{-1}). *Heteropogon contortus* showed minimum BC at N1 (10.65 cm^2 ha^{-1}) and *Viola canescens* at N2 (22.39 cm^2 ha^{-1}).

Invasive alien species, *Xanthium indicum* (IVI 58.12 at D2, 45.17 at D1) and *Parthenium hysterophorus* (IVI 56.46 at D2, 55.25 at D1) were two most dominant species at both the dumping sites. These two followed by *Euphorbia hirta* (IVI 28.29 at D1, 11.6 at D2), *Cannabis sativa* (IVI 20.23 at D2, 19.79 at D1) and *Ageratum conyzoides* (IVI 15.82 D2). Least dominant species at D1 was *Portulaca oleracea* (IVI 1.58) and *Euphorbia heterophylla* (IVI 1.23) at D2. Among native species at dumping sites, *Verbascum thapsus* (IVI 23.86 at D2), *Cynodon dactylon* (IVI 14.28 at D1, 10.05 at D2), *Panicum antidotale* (IVI 11.53 at D1) and *Crotalaria medicaginea* (IVI 10.5 at D1) were the dominant species. Most dominant species at N1 was *Cannabis sativa* (IVI 14.67) while *Cynodon dactylon* (IVI 12.4) at N2 while lest dominant species at N1 and N2 were *Inula cappa* (IVI 0.43) and *Corchorus aestuans* (IVI 0.39) respectively.

The phytosociological attributes (species composition, richness, density, TBC and diversity indices) of undumped natural sites studied presently have not showed much difference with that of the earlier studies (Ballabha, 2011; Saleep and Kumar, 2014). But, no earlier worker had studied the dumping sites and the present study throws light upon the impact of dumping on the quantitative facets of the vegetation. This study reported that the community dynamics at dumping sites dominated by *Xanthium indicum*, *Parthenium hysterophorus*, *Euphorbia hirta*, *Cannabis sativa* and *Ageratum conyzoides* among invasive species while, *Verbascum thapsus*, *Cynodon dactylon*, *Panicum antidotale* and *Crotalaria medicaginea* in native species. These species showed co–dominance at the natural sites thus it can be inferred that these species are more adaptive to the dumping sites which showed wider range of adaptability and rapid multiplication, and having capability to establish, invade newly denudate habitats. However, many of these species have potential to change the natural habitats by eradicating several habitat specific native species but can be considered important from the phytorestoration view of point at dumping sites. The biotic and abiotic properties of the targeted habitats are likely to be as important as the autecological attributes of the invading species in influencing invasive success.

The density-dominance curves (d-d curve) of herbs at different sites are presented in **Fig. 4**. The d-d curves for dumping sites (D1 and D2) indicated low evenness in IVI of high rank species, while d-d curves for natural sites (N1 and N2) indicated high evenness in dominance (IVI) of high rank species. In the present study, higher species richness, TBC and total density were observed at the undumped natural sites than those of the dumping sites. Because, plant community at natural sites were established long ago and are heterogeneous besides species showed co-dominance (most dominant species had IVI 14.67 at N1 and 12.4 at N2).

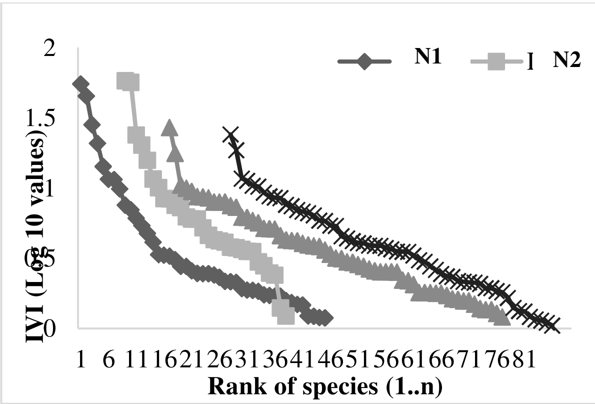

Fig. 4. Dominance-diversity curves (d-d curve) for herbs at different study sites.

Conclusion

Conditionally created habitats like debris dumping zones magnetized the encroachments of invasive alien species. A proper re-vegetation plan of such habitats will not only reduce the invasive alien but also check undesirable downward flow of the valuable natural resource like soil in such cases. For this purpose, emphasis should be given on native species (species with high IVI) because they are most likely to fit into a fully functional ecosystem and are climatically adapted or on nonproblematic invasive alien species. Seeds or propagules of selected species could be spreaded over newly dumping zones to the development of preliminary community. Re-vegetation of abandoned debris dumping zones in Western Himalaya using indigenous and costless measures would be effective in the sustainable environmental management.

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