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Vegetational Succession on Different Age Series Sponge Iron Solid Waste Dumps with Respect to Top Soil Application

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Abstract: Vegetation composition of different age series sponge iron solid waste dumps was analyzed with respect to the impact of top soil application on vegetation succession. Study revealed that freshly laid dump, without top soil cover was devoid of any vegetation. However, 1, 3 and 5 year old dumps were colonized by grasses, sedges, forbs and shrubs. Tree species could be recorded in 3 and 5 year old dumps, but were absent in 1 year old dump. In all the dumps, species belonging to forbs showed the highest percentage contribution to species composition which was followed by grasses. Common occurrence of certain plant species in all the dumps indicated their greater adaptability to the adverse condition of waste material. IVI of herbaceous plants gradually decreased with dump age which was replaced by occupation of shrub and tree species in older dump. Among the families, Poaceae dominated in all the dumps. Species richness and diversity showed increasing trend, where as dominance showed decreasing trend with increasing dump age. Patch with top soil cover always showed highest species richness, followed by mixed patch and lowest by the patch only with waste material. The study revealed that top soil acted as seed bank and its application on sponge iron solid waste dump positively contributed towards species richness and vegetation growth.

Key words: Derelict land, diversity, reclamation, species richness, vegetation composition

INTRODUCTION

Land degradation due to the alteration and destruction of terrestrial habitat has become a major environmental concern throughout the tropics. One of the major factors responsible for such degradation is rapid industrialization and spread of mining activity which often result in the loss of the natural ecosystem with associated biodiversity (Ezeaku and Davidson, 2008). Reclamation of the degraded land is essential for restoration of the self sustaining capacity of the ecosystem and its delicate equilibrium.

Coal based sponge iron industry usually generates huge amount of solid waste in the form of char, dust, sludge and fly ash (CPCB, 2007) and major part of the solid waste is disposed on land. Dumping of such industrial solid waste creates a large area of derelict land, which apart from reducing productivity, reduces aesthetic value of the landscape (Roy *et al.*, 2002). At present India is the largest producer of sponge iron with production of 20 million ton per annum (Anonymous, 2010). Looking at the present trend of sponge iron production and subsequent solid waste generation, reclamation of the sponge iron solid waste dump has become an urgent environmental issue in India. Among the various strategies for reclamation of waste and degraded land, top soil application seems to be one of the traditional strategies (Williamson and Johnson, 1981). Top soil is fundamentally an essential component in abandoned mines for growth and development of vegetation that further influences the success of reclamation (Kundu and Ghosh, 1994). There have been several reports about the vegetation composition of former metallurgical landfill, slag dump, abandoned mines and mine tailings (Forbes and Jefferies, 1999; Prach *et al.,* 2001; Pyšek *et al.*, 2003; Mohanty *et al.*, 2004; Remon *et al.*, 2005). There have been studies of vegetation succession on fly ash (Mulhern *et al.*, 1989; Elseewi and Page, 1984), industrial solid waste disposal site (Ettala, 1991) and coal mine spoil dumps (Jha and Singh, 1991; Singh, 2006; Hazarika *et al.*, 2006; Borpujari, 2008; Ekka and Behera, 2010) and such studies emphasizes the role of vegetation on the reclamation process. Reports about the vegetation composition and succession on iron industry solid waste dumps are relatively scanty (Pandey and Maiti, 2008). In the present study we analyzed the vegetation composition and succession with particular reference to the impact of top soil application on different age series sponge iron solid waste dump from Orissa, India, with a view to study the reclamation of the waste dump.

MATERIALS AND METHODS

Study site: The present study was carried out on the solid waste dump of Scan Steels Ltd., located at Sundargarh district of Orissa, India during August-November period of 2009. Geographically the area lies between 20º11′ N

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latitude and 84º19′ E longitude. Altitude of the area is about 245 m above the mean sea level. Climate of the area is tropical monsoonic, experiencing broadly three distinct seasons i.e., summer (March-June), rainy (July-September) and winter (October- February). The mean annual rainfall in the area is 1422 mm, 80% of which occurs during rainy season. Mean air temperature of the area varies from a minimum of 10ºC during December to a maximum of 45ºC during May. The relative humidity fluctuates from minimum of 40% (May) to maximum of 83% (August).

Scan Steels Limited got into manufacturing sponge iron in the year 2002. Its solid waste dumping site stretches over an area of 25 ha. Accumulation of solid waste over years resulted in formation of different age series of dumps. Dump age is expressed as time since the establishment of dump in the site. For the present study freshly laid dump (D_0), 1 year (D_1), 3 year (D_3) and 5 year (D_5) old dumps were selected. During dumping of the solid waste, when the dump attains sufficient height, a top layer of soil is covered over the dump. However, the soil cover is not uniform all over the dump. With such uneven top soil spread up, three types of patches are observed on the waste dump such as:

- Patch with top soil of average thickness 25 cm (S)
- Patch with mixed up top soil and solid waste (M)
- Patch with only solid waste (W)

Among the different age series dumps, D_1, D_3 and D_5 have top soil cover, however in D_0 there is no top soil cover. Hence S, M and W patches are observed in D_1, D_3 and D_5 whereas only W patch is observed in D_0.

Methods: The vegetation analysis of different age series sponge iron solid waste dumps (D_0, D_1, D_3 and D_5) was conducted during August-November, to cover all the spectrum of vegetation. Ecological enumeration of plant species were done according to quadrate sampling method (Mishra, 1968). The size of the quadrate for herbaceous vegetation was 1×1 m^2, for shrub 5×5 m^2 and for tree species 10×10 m^2. Vegetation data were quantitatively analyzed for relative values of density, frequency and abundance (Phillips, 1959). Importance Value Index (IVI) for individual plant species was determined as the sum of their relative density, relative frequency and relative dominance (Curtis, 1959). Family Importance Value (FIV) was calculated by summing up the IVI value of the individuals of the family. Species diversity (H') was determined as per Shannon and Weaver (1963) and Concentration of Dominance (Cd) as per Simpson (1949). Evenness index was calculated by following Pielou (1975). Sorenson's similarity index calculated using the formula as described by Singh (2006).

RESULTS

Vegetation composition of different age series sponge iron solid waste dumps was presented in Appendix 1. The data revealed that D_0 was devoid of any vegetation. Altogether 99 plant species (30 grasses, 7 Sedges, 48 forbs, 10 shrubs and 4 tree species) were recorded in 1 year (D_1), 3 year (D_3) and 5 year (D_5) old dumps. The number of grasses present in S (soil), M (mixed) and W (waste) patch of D_1 were 11, 7 and 5, respectively. Corresponding figures for D_3 were 20, 14 and 10, that of D_5 were 30, 22 and 12, respectively. With respect to D_1, the number of sedges recorded in S patch was 5, whereas in M and W patches numbers of sedge species recorded were 4 each. In D_3 and D_5 the number of sedges observed in S patch was 6 and 7, respectively. The number of sedges recorded in M and W patches of both D_3 and D_5 were 5 each. The number of forbs noticed to be present in D_1 were 18 in S patch, 15 in M patch and 12 in W patch. The number of forbs observed in D_3 were 37, 32 and 18 in S, M and W patches respectively. The number of forbs recorded in D_5 were 48 in S patch, 37 in M patch and 24 in W patch. In D_1 two and in D_3 five number of shrub species were recorded in all the patches (S, M and W), whereas in D_5 nine, six and five number of shrub species were observed in S, M and W patches respectively. In D_1, no tree species was recorded. However, in D_3, two tree species were observed in all patches. The number of tree species recorded on S and M patches of D_5 were 5 each and that of W patch were 3.

Among the grasses, *Eragrostis riparia, Eragrostis tenella and Eragrostis unioloides,* among the sedges *Cyperus iria, Cyperus kyllingia*, *Cyperus rotundous* and *Fimbristylis bisumbellata* were present in all the dumps (D_1, D_3 and D_5) and in all the patches (S, M and W). Among the forbs, *Tridax procumbense*, *Borreria hispida*, *Evolvulus alsinoides*, *Evolvulus nummularius*, *Ipomea obscura*, *Alysicarpus monilifer*, *Alysicarpus vaginalis*, *Desmodium triflorum*, *Oldenlandia corymbosa*, *Linderina ciliata* and *Linderina crustaceae* were common in S, M and W patches of D_1, D_3 and D_5. Among the shrubs, *Chromoleana odorata* and *Calotropis procera* were common in all the dumps, whereas tree species *Cassia siamea* and *Dalbergia sissoo* were observed in all the patch of D_3 and D_5. Considering IVI as the indicator of dominance, *Desmodium triflorum* (Fabaceae) was the dominant species in D_1 and D_3, but *Eragrostis tenella* (Poaceae) was the dominant species in D_5.

Data pertaining to the percentage contribution of different plant species to species composition in different age series waste dumps along with 3 different patches was illustrated in Fig. 1. In all the cases highest percentage of contribution came from forbs, followed by grasses, then by sedges which was followed by shrub and lowest percentage was contributed by tree species. For forbs, no

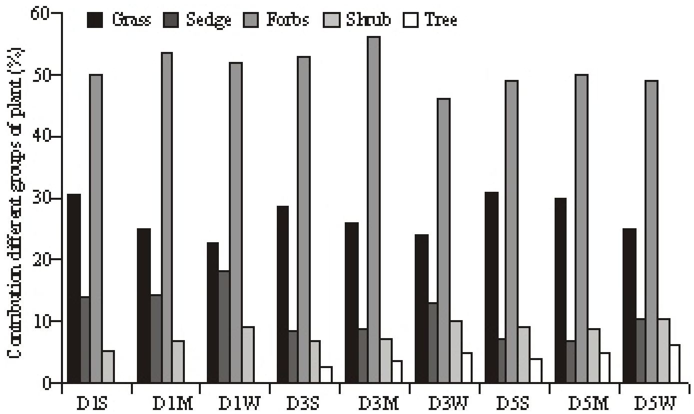

Fig. 1: Percentage contribution of different groups of plants to species composition in different age series sponge iron solid waste dumps along different patches. (D_1: 1 year old dump, D_3: 3 year old dump, D_5: 5 year old dump, S: soil patch, M: mixed Patch, W: waste Patch)

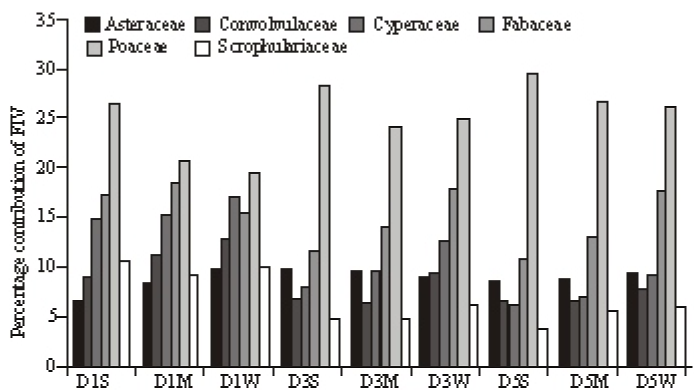

Fig. 2: Percentage contribution of FIV of different families to total FIV in different age series dumps. (D_1: 1 year old dump, D_3: 3 year old dump, D_5: 5 year old dump, S: soil patch, M: mixed Patch, W: waste Patch)

specific trend was observed in percentage contribution with respect to the age of the dump. However, the grasses showed increasing trend with increasing dump age. In a particular dump, S patch showed highest percentage of grasses, followed by M patch and W patch. In contrary, percentage contribution by sedges showed decreasing trend with increasing age of the dump, having highest percentage in W patch, followed by M patch and lowest in S patch. For shrub and tree species, the trend was increasing with increasing age of the dump.

The floristic diversity of different age series waste dump was affiliated to 26 families. Data related to the Family Importance Value (FIV) of different families were presented in Table 1. Families present in all the dumps including all the patches were Asclepiadaceae, Asteraceae, Boraginaceae, Convolvulaceae, Cyperaceae, Fabaceae, Poaceae, Rubiaceae and Scrophulariaceae. However, the families Asteraceae, Convolvulaceae, Cyperaceae, Fabaceae and Poaceae contributed $\geq$ 5% of the total FIV in a particular patch (Fig. 2). The families Amaranthaceae, Caesalpiniaceae, Lythraceae, Lamiaceae, Malvaceae, Molluginceae, Tiliaceae and Voilaceae were absent in D_1, but were present in D_3 and D_5. However the families like Arecaceae, Commelinaceae, Onagraeace, Polygelaceae and Verbenaceae were exclusively recorded only in D_5. Among all the families dominant was Poaceae, followed by Fabaceae in all the dumps.

A comparative account of different vegetational parameters is presented Table 2. The number of species, genus and family showed increasing trend with increasing age of the dump, where as within a particular dump, S patch recorded the highest number followed by M patch and the lowest number was in W patch. The value of Simpson's dominance index (Cd) varied from 0.052 to 0.013. It showed decreasing trend with increasing age of the dump, having the highest value in W patch of D_1 and the lowest in S patch of D_5. In contrary, the diversity index showed increasing trend with increasing dump age. The highest value of Shannon diversity index (4.490) was in S patch of D_5 and the lowest value (3.009) was in W patch of D_1. The value of evenness index (E') varied from 0.981 to 0.972.

Table 1: Family Importance Value (FIV) of different families in different age series sponge iron solid waste dumps

		D_1			D_3			D_5		
S. No.	Family	S	M	W	S	M	W	S	M	W
1	Amaranthaceae	_	_	_	10	13	10	9	10	12
2	Arecaceae	_	_	_	_	_	_	1	_	_
3	Asclepiadaceae	8	15	17	5	7	10	5	6	8
4	Asteraceae	19	25	30	30	29	27	23	25	29
5	Boraginaceae	8	11	12	5	6	9	4	7	8
6	Caesalpiniaceae	_	_	_	8	6	5	10	7	6
7	Commelinaceae	_	_	_	_	_	_	7	2	_
8	Convolvulaceae	27	33	38	20	24	28	20	21	23
9	Cyperaceae	45	46	51	23	29	38	20	21	28
10	Euphorbiaceae	7	8	_	15	16	9	16	18	10
11	Fabaceae	52	56	46	35	42	54	33	40	54
12	Lamiaceae	6	_	_	6	3	_	10	4	_
13	Lythraceae	_	_	_	2	2	_	2	_	_
14	Malvaceae	_	_	_	19	14	_	16	13	8
15	Mimosaceae	_	_	_	_	_	_	2	3	_
16	Molluginceae	_	_	_	4	4	6	2	3	5
17	Onagraceae	_	_	_	_	_	_	1	2	_
18	Poaceae	80	62	58	85	72	75	88	80	74
19	Polygelaceae	_	_	_	_	_	_	3	3	_
20	Rubiaceae	9	14	15	6	7	9	7	11	12
21	Scrophulariaceae	31	28	30	14	14	18	11	17	18
22	Solanaceae	4	4	3	3	4	4	2	3	_
23	Sterculiaceae	3	_	_	2	2	_	2	_	_
24	Tiliaceae	_	_	_	3	2	_	2	_	_
25	Voilaceae	_	_	_	3	4	_	2	3	5
26	Verbenaceae	_	_	_	_	_	_	2	2	_

D_1: 1 year old dump, D_3: 3 year old dump, D_5: 5 year old dump, S: soil patch, M: mixed patch, W: waste patch

Table 2: Comparative account of different vegetational parameters in different age series sponge iron solid waste dumps

	D_1			D_3			D_5		
Parameter	W	S	M	W	S	M	W	S	M
No. of Species	36	28	22	69	57	39	98	75	49
No. of Genus	28	21	16	51	36	31	73	58	37
No. of Family	13	10	8	20	20	14	26	22	15
Dominance index (Cd)	0.032	0.042	0.052	0.017	0.021	0.029	0.012	0.017	0.024
Diversity index (H')	3.515	3.240	3.009	4.159	3.949	3.581	4.490	4.214	3.798
Evenness index (E')	0.981	0.972	0.973	0.981	0.976	0.977	0.925	0.976	0.976

D_1: 1 year old dump, D_3: 3 year old dump, D_5: 5 year old dump, S: soil patch, M: mixed patch, W: waste patch

Table 3: Sorenson's Similarity index between different age series dumps along with different patches.

S. No.	Dump pair	Similarity index	S. No.	Dump pair	Similarity index	S. No.	Dump pair	Similarity index
1	D_1S & D_3S	0.685	4	D_1M & D_3M	0.658	7	D_1W & D_3W	0.556
2	D_3S & D_5S	0.826	5	D_3M & D_5M	0.860	8	D_3W & D_5W	0.860
3	D_1S & D_5S	0.530	6	D_1M & D_5M	0.543	9	D_1W & D_5W	0.619

D_1: 1 year old dump, D_3: 3 year old dump, D_5: 5 year old dump, S: soil patch, M: mixed patch, W: waste patch

Sorenson's similarity index for species composition, in a particular patch between different age series waste dump is presented in Table 3. The value of similarity index varied from 0.886 to 0.530. In all the patches the similarity index value was the highest between D_3 and D_5 pair and the lowest between D_1 and D_5 pair.

DISCUSSION

Solid wastes generated from iron industrial units are usually deficient in nutrients and have high metal contents, low hydrological regime and high pH (Pandey and Maiti, 2008; Roy *et al.*, 2002), which do not favour seed germination and consequent vegetation development. This explains the complete absence of vegetation on freshly laid dump (D_0), as noted in the present study. However, one to five year old dumps were noted to be colonized by different plant species. Trends of species richness and diversity increased with increase in the age, as observed in the study indicates, sequential colonization due to the plant succession confirming the observation of Singh *et al.* (2006) and Borpujari (2008) on different derelict inhospitable mining lands. On the other hand, dominance of plant species showed decreasing trend with increase in the age of the dump, this points out the usual inverse relationship between the diversity and the dominance (Mishra and Mishra, 1981).

The common occurrence of certain grasses, forbs, sedges and shrub species on all the three patches i.e. S, M and W of the different age series dumps indicates their adaptability to thrive inspite of adverse conditions of the waste material. Adaptability of some genera like *Eragrostis*, *Cyperus*, *Evovulus*, *Alysicarpus* and *Linderina* to survive and exist on the coal mine spoil of the area has already been reported by Ekka and Behera (2010). Common occurrence of *Calotropis procera* on all the patches of different age series dumps can be explained on the basis of its xerophytic characteristics (Saxena and

Brahmam, 1994). Common occurrence of *Chromoleana odorata,* considered to be an invasive species agrees with observation of Mohanty *et al.* (2004), who reported its vigorous colonization on abandoned mine lands. Dominance of *Desmodium triflorum* (Fabaceae) in D_1 and D_3 indicates that the leguminous species has more adaptability in early stage of succession. Dominance of *Eragrostis tenella* (Poaceae) in D_5 implies that the grass species is able to dominate the habitat, only after amelioration of the site by nitrogen fixing forbs.

Comparative analysis of the percentage contribution of different group of plant species to species composition in different age series dumps indicated the highest contribution by forbs, followed by grasses. As per Rice (1989), soil seed bank appears to contain more forbs which easily disperse to near by areas for colonization and this perhaps explains their higher contribution. Grasses, sedges and forbs showed greater importance value in younger dump like D_1, which is found to be replaced by the occupation of shrub and tree species in older dump (D_5), which may be as natural successional tendency of plant species (Hazarika *et al*., 2006). On the basis of the Family Importance Value (FIV), some of the important families like Poaceae, Fabaceae, Cyperaceae, Asteraceae and Convolvulaceae are noted to be prevalent during succession on the sponge iron waste dumps. Members of the family Poaceae have been reported to play positive role as the initial colonizer of the different derelict mine spoil (Helm, 1995; Singh, 2006). Absence of tree cover in D_1 but their presence in D_3 and D_5 indicates that at initial stage of succession tree species are unable to establish themselves. Amelioration of the site with inputs from the initially colonized herbaceous vegetation might have subsequently helped the tree species for their establishment in D_3 and D_5. Evenness index indicates the even distribution of plant species on different patches. With respect to similarity index, dumps with smaller age difference are much closer in terms of species composition than the dumps with larger age difference and this points out the sequential nature of plant succession process on the different age series dumps.

Relatively higher species richness and diversity in the top soil patches in comparison to the other patches of the dump as recorded in the present study, indicates the positive role of top soil application in the regulation of vegetational succession and consequent reclamation of the waste dumps. Importance of top soil for vegetation growth and development in derelict land has been well emphasized by different workers (Beauchamp *et al*., 1975; Howard and Samuel, 1979). According to Howard and Samuel (1979), top soil acts as the source of natural vegetation propagules and promotes species that can propagate from rhizomes and root crown material. Beauchamp *et al.* (1975) considered top soil to be the seed bank for achieving species diversity. Being the source of nutrients and organic matter, top soil acts as buffer, negating the adversities of the waste land. By the virtue of its textural structure, it ensures satisfactory hydrological regimes to nourish nurture and establish vegetaional cover (Bradshaw and Chadwick, 1980).

CONCLUSION

The study suggests that unfavourable physicochemical properties of the sponge iron solid waste inhibit the vegetation succession and development on freshly laid dump. How ever, top soil application on the waste dump promotes species diversity, vegetation succession and growth. Thus the study highlights the implication of top soil application for the restoration of the waste dump / derelict land

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Appendix 1:

				D_1			D_3			D_5		
S. No.	Name	Family	D_0	S	M	W	S	M	W	S	M	W
	Grass											
1	*Alloteropsis cimicina* (L.) Stapf.	Poaceae	_	5.39	4.38	3.56	3.22	2.60	_	2.11	2.00	_
2	*Aristidia adscensionis* L.	Poaceae	_	_	_	_	_	_	_	2.76	3.60	5.34
3	*Aristidia hystrix* L.f	Poaceae	_	_	_	_	4.85	5.55	6.54	3.12	4.32	6.10
4	*Bothricholoa pertusa* L.	Poaceae	_	6.07	_	_	3.99	_	_	2.29	_	_
5	*Chloris barbata* Sw.	Poaceae	_	_	_	_	_	_	_	3.80	2.00	_
6	*Cynodon dactylon* (L.) Pers.	Poaceae	_	_	_	_	3.19	4.87	6.45	2.19	3.70	7.60
7	*Dactyloctenium aegyptium* (L.) P. Beav.	Poaceae	_	6.10	5.32	_	4.85	4.56	3.50	4.50	4.00	3.40
8	*Dicanthium annulatum* (Forssk) Staff.	Poaceae	_	_	_	_	3.91	_	_	3.68	3.20	3.00
9	*Dicanthium aristatum* (Poir.) Hubbard.	Poaceae	_	8.20	_	_	3.68	3.50	_	2.91	2.10	_
10	*Digitaria biformis* Willd.	Poaceae	_	_	_	_	_	_	_	2.23	_	_
11	*Digitaria cilliaris* (Retz.)Koeler.	Poaceae	_	_	_	_	2.98	_	_	1.35	_	_
12	*Digitaria longiflora* (Retz.) Pers.	Poaceae	_	_	_	_	_	_	_	1.87	_	_
13	*Echinochola colona* (L.) Link.	Poaceae	_	_	_	_	4.61	5.70	6.40	3.05	3.34	4.00
14	*Eleusine indica (*L.) Gaerthn.	Poaceae	_	_	_	_	_	_	_	2.23	2.00	_
15	*Eragrostis riparia* Willd.	Poaceae	_	8.95	12.45	13.63	5.65	7.29	9.50	5.40	6.16	8.22

Appendix 1: continued

16	*Eragrostis tenella* (L.) P.Beav	Poaceae	_	14.68	18.34	20.56	10.54	11.88	16.56	9.13	10.96	13.65
17	*Eragrostis unioloides* Retz.	Poaceae	_	9.14	10.56	12.66	7.53	9.32	10.54	6.32	8.34	9.00
18	*Hemarthria compressa* (L.) R. Br.	Poaceae	_	_	_	_	_	_	_	2.12	2.00	_
19	*Iseilema anthephoroides* Hack.	Poaceae	_	_	_	_	_	_	_	3.56	3.20	_
20	*Leersia hexandra* Sw.	Poaceae	_	_	_	_	_	_	_	2.29	3.20	4.65
21	*Oplismenus burmanii* (Retz.) P.Beauv.	Poaceae	_	_	_	_	_	_	_	2.93	4.00	5.20
22	*Panicum notatum* Retz.	Poaceae	_	7.52	_	_	2.90	_	_	2.40	2.10	_
23	*Panicum psilopodium* Trin.	Poaceae	_	_	_	_	2.90	_	_	2.03	2.00	_
24	*Panicum repens* L.	Poaceae	_	_	_	_	_	_	_	2.50	_	_
25	*Panicum trypheron* Schult.	Poaceae	_	_	_	_	3.03	_	_	2.50	_	_
26	*Paspalidium flavidum* (Retz.) A. Campus	Poaceae	_	4.92	6.87	7.98	3.84	4.20	5.40	2.86	_	_
27	*Paspalum scorbiculatum* L.	Poaceae	_	4.27	_	_	2.33	2.64	3.95	1.03	1.89	_
28	*Saccharum spontaneum* L .	Poaceae	_	_	_	_	2.76	3.39	5.99	_	_	_
29	*Setaria glauca* (L.) P. Beauv.	Poaceae	_	4.60	3.95	_	3.80	2.96	_	2.66	3.40	4.20
30	*Sporobolus diander* Retz.P. Beauv.	Poaceae	_	_	_	_	4.38	3.68	_	2.34	2.00	_
	Sedge											
31	*Cyperus iria* L.	Cyperaceae	_	9.10	10.50	11.78	4.37	5.98	6.45	3.64	4.80	5.70
32	*Cyperus kyllingia* Endl.	Cyperaceae	_	10.31	11.40	12.40	5.85	7.43	8.89	4.53	6.00	7.40
33	*Cyperus puntitculatus* Vahl	Cyperaceae	_	7.89	_	_	2.76	_	_	2.23	_	_
34	*Cyperus rotundous* L.	Cyperaceae	_	8.46	11.45	12.89	3.59	5.88	7.87	2.54	3.60	6.50
35	*Cyperus tenuispica* Steud.	Cyperaceae	_	_	_	_	_	_	_	1.04	_	_
36	*Fimbristylis bisumbellata* Forssk. Bubani	Cyperaceae	_	9.10	12.40	13.79	2.91	3.76	5.77	2.55	3.56	4.34
37	*Fimbristylis ovata* (Burmf.) Kern.	Cyperaceae	_	_	_	_	4.01	6.00	8.86	3.20	3.36	3.79
	Forbs											
38	*Achyranthes aspera* L.	Amaranthaceae	_	_	_	_	6.65	7.34	9.75	4.70	6.54	7.50
39	*Celosia argentea* L.	Amaranthaceae	_	_	_	_				2.23	_	_
40	*Gomphrena celosioides* (Ait) R.Br	Amaranthaceae	_	_	_	_	3.19	5.70	_	2.19	3.50	4.30
41	*Ageratum conyzoides* L.	Asteraceae	_	_	_	_	3.78	4.76	_	3.78	5.30	6.00
42	*Blumea lacera* (Burm.f) D.C	Asteraceae	_	_	_	_	5.04	6.33	8.89	5.04	6.00	7.76
43	*Caesulia axillaris* Roxb.	Asteraceae	_	_	_	_	2.34	3.00	_	2.14	1.98	_
44	*Eclipta prostata* L. (L.)	Asteraceae	_	_	_	_	3.91	_	_	2.65	_	_
45	*Emilia sonchifolia* L.DC	Asteraceae	_	_	_	_	2.75	_	_	2.90	_	_
46	*Tridax procumbens* L.	Asteraceae	_	6.84	9.23	11.35	5.89	6.78	7.30	3.19	5.65	7.65
47	*Borreria hispida* (L.) K. Schum.	Boraginaceae	_	7.89	10.56	11.57	4.65	5.88	8.81	4.27	6.98	7.97
48	*Commelina benghalensis* L.	Commelinaceae	_	_	_	_	_	_	_	2.60	2.32	_
49	*Murdannia nudiflora* (L.) Brenan	Commelinaceae	_	_	_	_	_	_	_	2.30	_	_
50	*Tonningia axillaris* (L.) Kuntze	Commelinaceae	_	_	_	_	_	_	_	2.04	_	_
51	*Evolvulus alsinoides* (L.) L.	Convolvulaceae	_	6.68	7.48	8.78	5.78	6.35	7.56	4.52	5.80	6.50
52	*Evolvulus nummularius* (L.) L.	Convolvulaceae	_	7.65	9.27	10.94	6.26	7.86	9.83	5.78	6.20	7.30
53	*Ipomea obscura* Ker-Gawl.	Convolvulaceae	_	12.90	16.70	18.69	8.36	9.45	10.54	6.52	8.30	9.20
54	*Merremia tridentata* (L.) Hall. f.	Convolvulaceae	_	_	_	_	_	_	_	1.76	_	_
55	*Euphorbia hirta* L.	Euphorbiaceae	_	6.84	8.21	_	5.50	7.60	8.79	4.61	5.90	7.50
56	*Phyllanthus fraternus* Webster	Euphorbiaceae	_	_	_	_	3.86	3.20	_	2.64	2.34	_
57	*Phyllanthus simplex* Retz.	Euphorbiaceae	_	_	_	_	2.92	2.60	_	2.45	2.29	_
58	*Phyllanthus urinaria* L.	Euphorbiaceae	_	_	_	_	2.79	2.54	_	2.65	2.10	_
59	*Sebastiania chamaelea* (L.) Muell.-Arg	Euphorbiaceae	_	_	_	_	_	_	_	1.95	2.86	_
60	*Aeschynomene indica* L.	Fabaceae	_	10.91	9.54	_	5.63	6.65	8.65	4.63	5.30	7.43
61	*Alysicarpus monilifer* (L.)DC.	Fabaceae	_	8.95	10.88	11.65	6.13	7.43	9.40	3.31	5.10	7.72
62	*Alysicarpus vaginalis* (L.)DC.	Fabaceae	_	7.89	9.26	10.18	3.29	5.67	8.54	2.70	3.23	6.85
63	*Desmodium triflorum* (L.)DC.	Fabaceae	_	18.06	22.84	24.59	10.64	11.55	13.98	8.40	9.10	14.23
64	*Indigofera enneaphylla* L.	Fabaceae	_	_	_	_	_	_	_	2.94	3.20	6.74
65	*Medicago sativa* L.	Fabaceae	_	_	_	_	_	_	_	2.43	2.86	_
66	*Zornia diphylla* auct. non (L.) Pers .	Fabaceae	_	6.00	3.10	_	4.60	5.32	6.39	3.63	4.57	5.32
67	*Leucas aspera* (Willd.) Link.	Lamiaceae	_	6.07	_	_	3.54	3.10	_	3.23	3.50	_
68	*Leucas cephalotus* (Roth) Spreng	Lamiaceae	_	_	_	_	2.48	_	_	3.36	_	_
69	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	_	_	_	_	_	_	_	2.50	_	_
70	*Ammania baccifera* L.	Lythraceae	_	_	_	_	2.45	2.20	_	2.03	_	_
71	*Sida acuta* Burm f.	Malvaceae	_	_	_	_	5.79	4.30	_	4.64	3.69	2.85
72	*Sida rhombifolia* L.	Malvaceae	_	_	_	_	4.36	3.80	_	4.27	3.23	2.43
73	*Sida cordata* (Burm f.) Borssum	Malvaceae	_	_	_	_	6.17	5.40	_	4.21	3.58	2.24
74	*Urena sinuota* L.	Malvaceae	_	_	_	_	2.64	_	_	3.20	2.57	_
75	*Mollugo pentaphylla* L.	Molluginceae	_	_	_	_	3.74	4.32	5.77	2.11	3.05	5.32
76	*Ludwigia parviflora* Roxb.	Onagraceae	_	_	_	_	_	_	_	1.35	2.29	_
77	*Polygala chinesis* autt. non. L.	Polygelaceae	_	_	_	_	_	_	_	2.54	2.56	_
78	*Oldenlandia corymbosa* L.	Rubiaceae	_	9.10	13.60	14.74	6.48	7.34	8.98	4.35	7.48	8.45
79	*Linderina ciliata* (Colsm.) Pennell	Scrophulariaceae	_	12.14	13.23	14.21	5.42	6.66	8.45	4.86	6.25	9.65
80	*Linderina crustaceae* (L.) F.v.Muell.	Scrophulariaceae	_	12.04	14.80	15.54	6.28	7.60	9.43	4.23	6.78	8.34
81	*Scoparia dulcis* L.	Scrophulariaceae	_	7.28	_	_	2.70	_	_	2.33	3.65	_
82	*Solanum surattense* Burm f.	Solanaceae	_	4.10	3.60	3.34	2.63	3.50	4.00	2.06	2.50	_
83	*Melochia chorchorifolia* L.	Sterculiaceae	_	3.07	_	_	2.33	2.10	_	1.87	_	_
84	*Corchorous aestuans* L.	Tiliaceae	_	_	_	_	3.03	2.45	_	1.65	_	_
85	*Hybanthus enneaspaermus* (L.) F.v. Muell.	Voilaceae	_	_	_	_	2.98	3.56	_	2.25	3.33	4.74
	Shrub											
86	*Leonotis nepetifolia* (L.) R. Br.	Lamiaceae	_	_	_	_	_	_	_	1.06	_	_
87	*Chromoleana odorata* L.	Asteraceae	_	12.64	15.56	18.50	6.17	8.35	10.87	3.25	5.86	7.74
88	*Phoenix acaulis* Buch -Ham. ex Roxb.	Arecaceae	_	_	_	_	_	_	_	1.04	_	_

Appendix 1: continued

89	*Calotropis procera* (Ait) R. Br.	Asclepiadaceae	_	7.92	14.61	16.76	5.21	6.50	9.78	4.83	6.29	7.95
90	*Cassia occidentalis* L.	Caesalpiniaceae	_	_	_	_	_	_	_	1.92	_	_
91	*Cassia tora* L.	Caesalpiniaceae	_	_	_	_	5.62	4.50	3.70	4.36	3.50	2.86
92	*Ipomea carnea* Jacq.	Convolvulaceae	_	_	_	_	_	_	_	1.04	1.00	_
93	*Jatropha gossypifolia* L.	Euphorbiaceae	_	_	_	_	_	_	_	2.04	2.94	2.75
94	*Crotalaria pallida* Ait.	Fabaceae	_	_	_	_	2.91	3.74	4.76	1.91	2.64	3.20
95	*Lantana camara* L.	Verbenaceae	_	_	_	_	_	_	_	2.04	2.00	_
	Tree											
96	*Cassia siamea* Lam.	Caesalpiniaceae	_	_	_	_	2.73	1.50	1.20	3.45	3.94	3.13
97	*Dalbergia sissoo* Roxb.	Fabaceae	_	_	_	_	2.16	2.00	1.80	3.25	3.53	2.50
98	*Acacia arabica* auct. non (Lam.) Willd.	Mimosaceae	_	_	_	_	_	_	_	1.78	2.75	_
99	*Nauclea parvifolia* Roxb.	Rubiaceae	_	_	_	_	_	_	_	2.34	3.23	3.45

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