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Temporal Assessment of Plant Community Attributes of Arid Saline Habitats

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ABSTRACT

We quantified the seasonal variations in the phytodiversity and related parameters at saline patches located in the western hot arid parts of the Rajasthan, India. High phytodiversity was recorded during the rainy season which gradually decreased from winter to summer seasons. Log-normal, broken-stick and geometric dominance diversity curves were observed during three sampling periods that showed the changing behavior of communities in response to seasons. Presence of generalized and or specialized species affected the community specialization index that can be used as an important ecological indicator compared to traditional indictors. We found only random and clumped distribution of species. Finally, groups of specific saline grass with woody perennials during resourceful (rain), moderate (winter) and non-resource (summer) conditions were identified through Agglomerative Hierarchical Cluster analysis. This study would help us to develop more resilient saline arid lands as well as for bioremediation of such lands.

Key Words: Phytodiversity; Community Specialization Index; Cluster Analysis; *Aeluropus lagopoides; Salsola baryosma; Suaeda fruticosa,* Rajasthan

INTRODUCTION

Salinity is a global problem and according to ICAR-Centre Soil Salinity Research Institute (www.cssri.org) around 195571 hectare area of Rajasthan state of India is affected by this problem. Salt affected area of this region can be divided into two parts: (i) the salt lakes, such as the Sambhar, Didwana and Kuchaman, located in the eastern part of the Rajasthan; and (ii) the salt basins like the Pachpadra, Thob, Sanwarla, Bap (Bap Malhar), Pokaran, Lunkaransar, Lanela (Kharia, Kanodwala and Mitha Ranns), Sakhi and Khajuwalla and Kaparda are located in the western half of Rajasthan (Sen et al., 1982). These salt basins having less than 1 % slope, are located in the hilly and sand-dune tracts where local run-off collects. This collected water evaporates and basins dry up. Upon dehydration, the surface layers become covered with a white crust of salt in the form of patches which consist of clay soils with evaporate deposits like sodium chloride, sodium sulphate, potassium chloride, magnesium sulphate, gypsum, nitrates and other salts (Roy 1999). Sharma and Mehra (2009) reported *Suaeda fruticosa* type vegetation for these areas with other halophytic associates like *Haloxylon saliconicum, H. recurvum, Salsola harmela* and *Zygophyllum simplex.*

Ecological surveys of these areas revealed high species diversity during the rainy season and minimum during summers, however, certain species like *Cynodon dactylon, Sporobolus diander, Indigofera linifolia* and *Prosopis cineraria* flourished round the year (Dagar 2005). Despite many qualitative surveys on such areas conducted by institutions like the Central Arid Zone Research Institute (CAZRI), Gujarat Ecological Education and Research Foundation (GEER) and the Indian Space and Research Organisation (ISRO), no quantitative effort have been made to understand the temporal dynamics of phytosociological attributes of these lands. Thus, the major objectives of the present study were:

- To quantify the temporal fluctuation in the phyto-diversity of saline patches located at the western (Pachpadra and Kaparda) and eastern (Didwana) hot arid parts of Rajasthan.
- To evaluate the quantitative floristic similarity between the saline patches.
- To assess temporal changes in the spatial distribution patterns of major saline species, and
- To group the species on the basis of their seasonal ecological dominance for their reintroduction or use them for rehabilitation/re-allocation.

MATERIAL AND METHODS

Three saline inland sites, namely Pachpadra (site-I), Didwana (site-II) and Kaparda (site-III) were selected for the detailed phytosociological survey (Table 1). At each site ten nested quadrats were employed for (5m x 5m for woody perennials and 1m x 1m for annuals to quantify temporal vegetation dynamics (Kent and Cooker 1992). Phytosociological parameters and their relative values were assessed following standard procedures (Shannon-Weaver 1963 and Simpson 1949). The species richness is defined as the total number of species per sampling unit (Maranon and Garcia 1997, Oba et al. 2001, Bhattarai 2004). Site similarity during various temporal events was quantified by Sorensen Similarity Index (Ariyo et al. 2012)

Dominance Diversity curves were prepared for measuring abundance trends in communities over time at each site with the help of Biodiversity Pro software. Community Specialization Index (CSI) of species assemblage was calculated for three temporal events viz., summer (May) rainy (August) and winter (January) seasons at each site. CSI is the proportion of community mean important value index (IVI) and their standard deviation (i.e. variance) at a site during particular seasonal (Kampichler et al. 2012).

Variability in spatial distribution pattern of every species across different seasons was evaluated by Index of Dispersion (see Mathur and Sundaramoorthy 2012). This index was calculated for the species that were present during more than two sampling periods and sites. Species assemblages (based on their IVI values) at each site during three different seasons were evaluated through Agglomerative Hierarchical Clustering (Statstica software). This multivariate tool was computed with Pearson correlation, coefficient of similarity and unweighted pair group average.

RESULTS AND DISCUSSION

Site Characteristics

Soil profile of the selected sites revealed that whereas dominant sub-equal proportion of fine sand and coarse sand, and coarse sand and gravel are the characteristic features of site 1 and 2, respectively, site 3 differed from them with dominant coarse sand texture (Table 1).

Species Composition

During the study, a total of 49 herbaceous and shrub species were recorded that belonged to 16 families and 41 genera (Figure 1) dominated by Poaceaefollowed by Cyperaceae and Fabaceae. The species recorded during rainy, winter and summer seasons were 48, 21 and 15 respectively, at the studied sites (Table 2). During the rainy season, site wise species richness ranged from 17 (S3) to 27 (S1) which dropped to 9 (S2) to 15 (S1) during winter and 6 (S2) to 11 (S1) during summer season (Table 3). Among the halophytic grasses and other species, dominance of *Aeluropus lagopoides, Cressa cretica*, *Salsola baryosma* and *Suaeda fruticosa* increased from rainy to winter and winter to summer season at their respective sites (Table 2). However, *Sporobolus helvolus* was recorded only during rainy and winter seasons with IVI of 24 (S1 rainy season) to 63 (S1

Table 1. GPS locations and basic soil features of the three studied sites

Site	Coordinates		Soil Texture				
	N	E	Clay	Silt	Fine Sand	Coarse sand	Gravel
S1 Pachpadra	25° 91' 51"	72° 06' 81"	0.8	0.3	54.6	32.6	11.5
S2 Kaparda	26° 28' 32"	73° 44' 49"	0.05	0.1	7.2	46.1	46.2
S3 Didwana	27° 23' 8"	74° 34' 56"	0.1	0.3	19.3	75.5	4.6

Table 2. IVI of different species (nomenclature after Bhandari 1990) recorded during three seasonal events

S. N.	Species*	Rainy S1	Rainy S2	Rainy S3	Winter S1	Winter S2	Winter S3	Summer S1	Summer S2	Summer S3
1	*Aeluropus lagopoides* (L.) Thwaite	19	23	36	78	139	88	116	127	113
2	*Aerva persica* (Burm.f.) Merrill	8	0	0	9	0	0	0	0	0
3	*Aristida funiculata* Trin. Et Rupr.	10	0	0	0	0	0	0	0	0
4	*Blepharis sindica* T. Anders.	3	0	0	8	0	0	0	0	0
5	*Boerhavia diffusa* Linn.	8	0	10	0	0	0	0	0	0
6	*Capparis decidua* (Forsk.) Edgew.	0	0	3	0	06	0	0	10	
7	*Calotropis procera* (Ait.) R.Br.	0	4	0	0	27	0	0	23	0
8	*Cassia fistula* L.	1	0	0	0	0	0	0	0	0
9	*Cenchrus biflorus* Roxb.	0	16	0	0	0	0	0	0	0
10	*Cenchrus setigerus* Vahl	13	0	0	0	0	0	0	0	0
11	*Chloris virgata* Sw.	17	37	43	0	0	0	0	0	0
12	*Convolvulus auricomus* (A.Rich.) Bhandari	5	0	0	6	0	0	9	0	0
13	*Corchorus depressus* (Linn.) Christensen	0	0	12	0	0	0	0	0	0
14	*Corchorus tridens* Linn.	0	7	0	0	0	0	0	0	0
15	*Cressa cretica* Linn.	20	0	28	41	11	28	59	61	67
16	*Crotolaria burhia* Buch.-Ham.	0	5	8	4	5	0	5	0	0
17	*Cyperus arenarius* Retz.	0	10	0	0	0	0	0	0	0
18	*Cyperus bulbosus* Vahl	0	0	31	0	0	0	0	0	0
19	*Cyperus iria* Linn.	0	10	0	0	16	0	0	0	0
20	*Cyperus rotundus* Linn.	0	10	0	0	0	0	0	0	0
21	*Cyperus compressus* Linn.	13	0	0	0	0	0	0	0	0
22	*Dactyloctenium aegyptium* (Linn.) P. Beauv.	18	37	15	0	0	0	0	0	0
23	*Dicoma tomentosa* Cass.	0	0	4	0	0	0	0	0	0
24	*Eleusine compressa* (Forsk.) Aschers. et Schweinf	13	0	0	0	0	0	0	0	0
25	*Eragrostis ciliaris* (Linn.) R. Br.	0	31	21	0	0	0	0	0	0
26	*Eragrostis tremula* Hochst.	0	10	0	0	0	0	0	0	0
27	*Fagonia indica* Burm.f.	7	0	7	8	0	10	16	0	0
28	*Farsetia hamiltonii* Royle	10	0	0	0	0	0	0	0	0
29	*Haloxylon recurvum* (Moq.) Bunge ex Boiss.	11	0	0	0	0	0	0	0	0
30	*Heliotropium curassavicum* Linn.	8	0	0	0	0	0	0	0	0
31	*Heliotropium marifolium* Koen ex Retz.	9	33	0	0	13	0	0	0	0
32	*Indigofera cordifolia* Heyne ex Roth	6	0	0	0	0	0	0	0	0
33	*Leptadenia pyrotechnica* (Forsk.) Decne.	4	2	0	5	10	0	11	14	0
34	*Melanocenchrus jacquemontii* Jaub. et Spach.	0	0	23	0	0	0	0	0	0
35	*Oligochaeta ramosa* (Roxb.) Wagenitz	0	0	0	4	0	0	0	11	0
36	*Polygala chinensis* L.	10	0	0	0	0	0	0	0	0
37	*Prosopis juliflora* (Swartz) DC.	3	0	0	0	0	0	0	0	0
38	*Pulicaria wightiana* (DC.) Clarke	12	0	0	0	0	0	0	0	0
39	*Salsola baryosma* (Roem. et Schult.) Dandy	3	0	0	6	0	0	8	0	0
40	*Scirpus tuberosus* Desf.	0	9	0	0	0	11	0	0	0
41	*Senna angustifolia* (Del.) Batka	1	0	0	10	0	0	13	0	0
42	*Sonchus asper* (L.) Hill	0	5	10	12	0	41	9	0	34
43	*Sporobolus helvolus* (Trin.) Th. Dur. Et Schinz	24	0	0	63	0	44	0	0	0
44	*Suaeda fruticosa* (L.)Forsk.	10	18	8	15	71	10	19	65	29
45	*Tamarix aphylla* (L.) Karst.	0	0	3	0	0	3	0	0	4
46	*Tephrosia purpurea* (L.) Pers.	6	3	10	4	0	0	0	0	0
47	*Tragus roxburghii* Panigrahi	0	28	10	0	0	0	0	0	0
48	*Tribulus terrestris* Linn.	7	0	0	0	0	0	0	0	0
49	*Vernonia cinerea* (L.) Less.	11	0	21	18	0	50	14	0	42

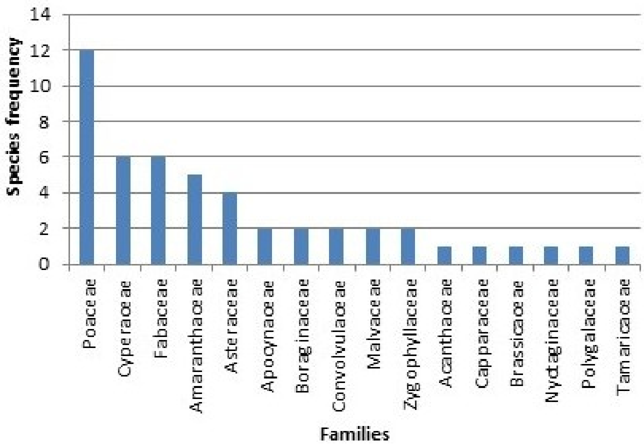

Figure 1. Species frequency with respect to families

winter season). Seasons-wise 17 different grass / sedge species were recorded during the rainy season which dropped to 5 during rest of the year and *Oligochaeta ramosa* was recorded as new species.

Species Diversity

Values of two diversity indices viz. Shannon and Weaver index (H') and Simpson index during different seasons and in different habitats are given in Table 3. Value of Shannon and Weaver index varies from 1.5 to 3.5 and rarely surpasses 4. Higher value indicates more diversity and vice-versa and this index is highly influenced by rare species. Simpson index represents the Dominance of Concentration (DC). Lower DC indicates sharing of dominance by many species and high DC values denote dominance of one (or a few) species indicating unequal sharing of resources. In the present study, higher diversity (high H' and DC) values were recorded during rainy seasons; they continuously declined during other two sampling periods (Table 3). Among the sites, site one was identified as richer and diversified than the other two sites.

Site Similarity

Season wise site similarity values presented in Table 4 reveal high sites similarities during summer season (>70%) and lowest during the rainy seasons. In comparison with site S2, site S1 showed more similarity with site S3 (70%) during winter season, while sites S2 and S3 were more similar during rainy season than the site S1. High site similarities during summer season can be explained with the high proportion of perennials while lowest during rainy season due to greater presence of the annuals.

Dominance Diversity Relation

Dominance-Diversity curves at three studied sites during three seasons are depicted in Figure 2. Within a plant community three basic types of distribution can be found viz. geometric, broken-stick and lognormal. We observed a clear impact of temporal factor on plant community

Table 3. Diversity parameters of at three studied sites during different seasonal events

Diversity Parameters	Rainy			Winter			Summer		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Richness	27	18	17	15	9	10	11	6	7
Shannon Index	1.4	1.1	1.1	0.94	0.69	0.86	0.8	0.64	0.7
Simpson Index	0.04	0.07	0.07	0.15	0.28	0.16	0.23	0.27	0.23

Table 4. Site Similarity (Sorensen Index) values in three seasons

	Rainy			Winter			Summer		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
S1	-	26.5	37	-	38.9	70	-	70.7	74.2
S2	-	-	42.5	-	-	36.5	-	-	68

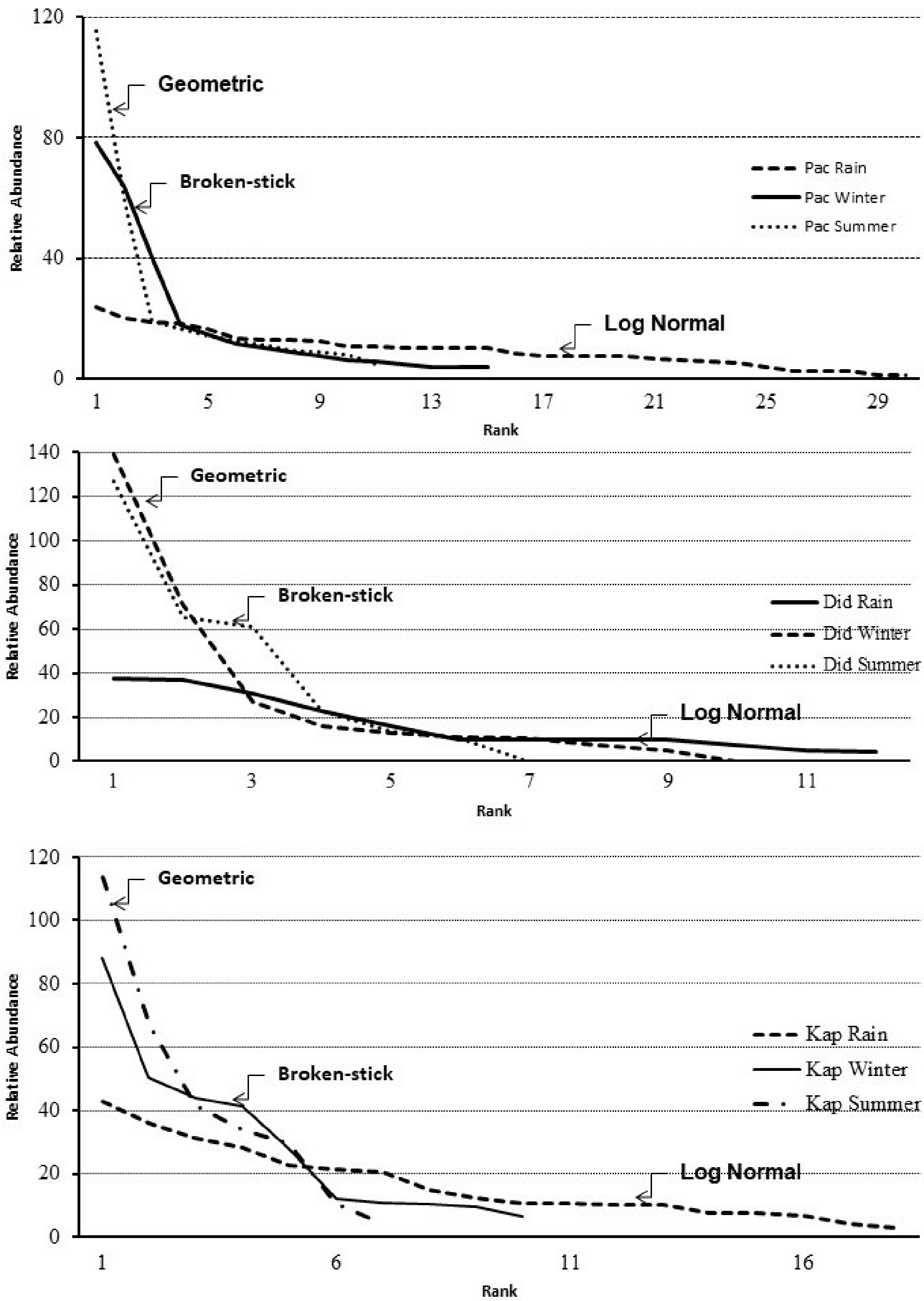

Figure 2. Diversity Dominance Curve at sampling sites during three sampling periods

distribution pattern at selected habitats. We found log normal, broken-stick and geometric models during rainy, winter and summer seasons respectively, at all the sites. On log-normal model, peak of the curve was represented by *S. helvolus* (23.9 IVI), *Dactyloctenium aegyptium* (37.5 IVI) and *Chloris virgata* (42.7) at site 1, 2 and 3, respectively, whereas the tail of DD curves at these sites was represented by *Cassia fistula* (1.1 IVI), *Leptadenia pyrotechnica* (2.2 IVI) and *Tamarix aphylla* (2.8 IVI) respectively. The lognormal dominance–diversity curves indicate the heterogeneity of the species (May 1975). Lognormal hypothesis assumes that the importance of species is governed by the interactions between a large numbers of factors determining success in the niche hyperspace (Whittaker 1970). Whittaker (1965) noted that the log-normal series describes the partitioning of realized niche space among various species and is the consequence of the evolution of particular species diversity along the niche parameters which they exploit. Similar types of dominance–diversity curves have been reported in Harshin rangelands of the Somali Regional State in Eastern Ethiopia by Hailu (2017).

Geometric distribution type prevails in a relatively species poor community where a single environmental resource (like moisture) is extremely important to species survival and is utilized in a strongly hierarchical fashion. Under such condition a single dominant species preempts a large fraction of the resource; the next most successful species preempts a smaller fraction of the remaining resources and so forth. Broken-stick model assumes that the species in a community partition or utilize some critical resources with no overlapping between the species while large species assembly with sub-equal abundance is the characteristic feature of log normal model (Clark 1990). Interestingly, in our study *A. lagopoides* (a saline grass) was identified a dominant species at the peak of broken-stick and geometric models during winter and summer seasons, while *Tephrosia purpurea, Crotalaria burhia* and *Capparis decidua* were the tail species of broken stick model at three sites, respectively. Similarly tails of geometric model were occupied by *C. decidua, O. ramosa* and *T. aphylla*. Such findings would help us to create more resilient and sustainable plant community created with the deliberate introduction of species with similar resource demand and acquisition capability.

Community Specialization Index

At the community level, a community specialization index (CSI) of species assemblages can be calculated as the average of each species SSI present in the assemblage (Devictor et al., 2008). Declining value of CSI indicates an increase of generalist species while its higher value shows higher proportion of specialized species of particular site (Vimal and Devictor 2014). We found CSI values of 1.60, 2.77 and 2.94 during rain, winter and summer sampling period, respectively. Lower value of CSI during the rainy or resourceful period was due to addition of more generalized species in the community like *Aerva persica, Blepharis sindica, Boerhavia diffusa, Convolvulus auricomus, Farsetia hamiltonii, Dicoma tomentosa, Pulicaria wightiana, Sonchus asper* and *Chorchorus tridens*. Higher values of this index during the other two seasons were due to dominant presence of more specialized species like *A. lagopoides, C. cretica, Suaeda fruticosa,* and *S. helvolus*. These species are indicators of saline habitats. Thus, this index can be used as an interesting ecological indicator complementary to more traditional indicators based on diversity (Filippi-Codaccioni et al., 2010, Abadie et al. 2011). Mapping the CSI can thus provide a picture of spatial variation in the specialization level of communities, which can be related to independent sources of disturbance or used as a spatial guideline to identify sites of conservation interest (Devictor et al. 2008). This finding further linked with our spatial distribution of pattern of every species across different seasonal events.

Spatial Distribution Pattern

Based on the Index of Dispersion (I_D), we got two types of spatial distribution i.e. random and clumped or aggregation (Table 5). Thus, our analysis revealed the absence of uniform pattern types of plant species on saline habitats. Based on available plant species during sampling seasons *Calotropis procera. Convolvulus auricomus, Sonchus asper, Vernonia cinerea, Aerva persica, Cyperus iria, Heliotropium marifolium, Scirpus tuberosus* and *S. helvolus* represented clumped distribution pattern type only, while species like *Senna angustifolia, Fagonia cretica, Leptadenia pyrotechnica, Salsola baryosma, Suaeda fruticosa, Blepharis sindica* and *Tephrosia purpurea* showed temporal shifts in spatial distribution pattern from random (rain) to aggregated (winter and summer). *A. lagopoides* showed random to clumped and clumped to random pattern during rainy-winter and winter –summer, respectively. *C. cretica* and *C. burhia* showed temporal shifts from clumped to random and random to clumped, respectively. Thus, such information's would also help us understand the introduction strategies of these species for reallocation and rehabilitation of the degraded lands. Such information's indicating their probable population traits that may link with their stable population leading to facilitation with other community variables and thus, support the system stability

This analysis also provides an insight about the post emergence species behavior within the community and its preference and non-preference companion.

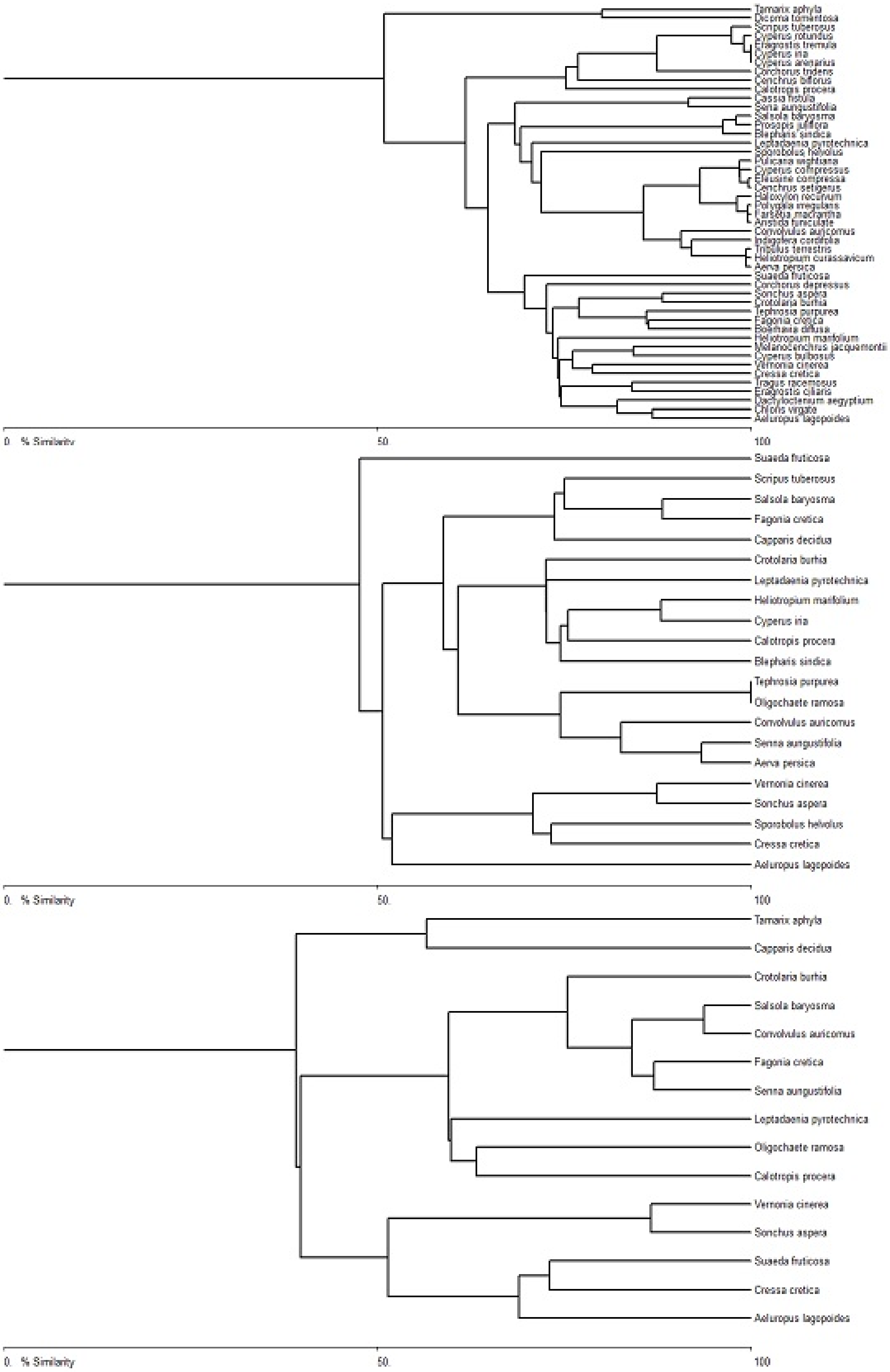

Figure 3. Agglomerative Hierarchical Clustering during rainy, winter and summer seasons (top to bottom)

Table 5. Species distribution patterns during study period

Species	Rain	Winter	Summer
Aeluropus lagopoides	Random	Aggregated	Random
Aerva persica	Aggregated	Aggregated	-
Blepharis sindica	Random	Aggregated	-
Calotropis procera	Aggregated	Aggregated	Aggregated
Convolvulus auricomus	Aggregated	Aggregated	Aggregated
Cressa cretica	Aggregated	Aggregated	Random
Crotolaria burhia	Random	Random	Aggregated
Cyperus iria	Aggregated	Aggregated	-
Fagonia indica	Random	Aggregated	Aggregated
Heliotropium marifolium	Aggregated	Aggregated	-
Leptadenia pyrotechnica	Random	Aggregated	Aggregated
Salsola baryosma	Random	Aggregated	Aggregated
Senna angustifolia	Random	Aggregated	Aggregated
Scirpus tuberosus	Aggregated	Aggregated	-
Sonchus asper	Aggregated	Aggregated	Aggregated
Sporobolus helvolus	Aggregated	Aggregated	-
Suaeda fruticosa	Random	Aggregated	Aggregated
Tephrosia purpurea	Random	Aggregated	-
Vernonia cinerea	Aggregated	Aggregated	Aggregated

Agglomerative Hierarchical Clustering (AHC)

AHC dendrograms for species assemblage during three sampling periods using multivariate tool grouped the species on the basis of their IVI similarities and that provided good information about the selection of species for restoration/rehabilitation of degraded land with minimum competition for resources. During the rainy season AHC provided two distinct groups (Figure 3). Group one started with *A. lagopoides* and ended with *C. auricomus*, with total 22 species while group two started with *Aristida funiculata* and ended with *T. aphylla* having 25 species. Group one which has only two saline species. i.e. *A. lagopoides* and *S. fruticosa* and seven woody perennials like *A. persica, Corchorus depressus, C. burhia, T. purpurea, F. cretica, Boerhavia diffusa, Vernonia cinerea.*

Group two with four saline species i.e. *T. aphylla, S. baryosma, S. helvolus* and *Haloxylon recurvum* with woody perennials like *L .pyrotechnica, B. sindica, Prosopis juliflora, Senna angustifolia, Cassia fistula, C. procera.* However, this group had more grasses (total 10) than group one (6). During winter season (Figure 3), we got a different scenario in which *A. lagopoides* showed proximity with *S. helvolus* and *S. fruticosa* with *S. baryosma.* This further changed during the summer seasons where both *A. lagopoides* and *S. fruticosa* showed proximity with each other compared to *S. baryosma* (Figure 3).

Thus, with such analysis we can recommend the specific group of saline grasses with woody perennials during resourceful condition to moderate and non-resource conditions. That is *A. lagopoides- S. fruticosa* and *T. aphylla–S. baryosma-S. helvolus–H. recurvum* with woody perennials during rainy seasons, *A. lagopoides- S. helvolus* and *S. fruticosa- S. baryosma* with woody perennials during winter seasons and *A. lagopoides-S.fruticosa* and *S. baryosma* with woody perennials during summer seasons. Such pattern can be very useful for bioremediation of such lands, i.e. their potential to manage soil properties up to a certain threshold level and thus, can check further land degradation. However, assessments of bottom-up and top-down factors will further guide us for understanding underlying mechanisms.

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