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Natural Plant Communities in View of Response Variables and Ecological Indices from Lalsuhanra Biosphere Reserve, Pakistan

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Abstract: The present study aimed to investigate the ecology of vegetation and to see if the heterogeneity of soil is the main determining factor for the diversity of natural vegetation. Therophytes were the most prominent proportion of life-form spectrum. On the basis of highest IVI three plant communities, *Ochthochloa-Cymbopogon-* Community, *Launaea-Aerva-* Community and *Lasiurus scindicus*-Community were recognized at the three selected habitats. Measurements for ecological indices showed that *Launaea-Aerva-* Community was more diverse with regard to species number, richness and evenness as compared to the other two plant communities studied. Present results for the pearson moment correlation showed that soil chemical composition may be the main factor not only for array of vegetation but also determines that what type of plant species can grow there. Soil variables were found highly different at all the study sites. We concluded that soil heterogeneity is the major determinant for development of plant communities while climate do not differ much in the area.

Key words: Floristic composition, importance values, physiognomy, soil heterogeneity, species richness, species evenness

INTRODUCTION

The Lal-Suhanra Biosphere Reserve Pakistan encompasses a part with Northern fringes of Lesser Cholistan, about 32 km from the Bahawalpur city towards East at the main Bahawalpur- Bahawalnagar highway and 2 km towards South from Lal-Suhanra railway station in Province of Punjab (Southern), Pakistan. It lies between 29°12′ to 29°28′ N latitude and 71°48′ to 72°08′ E longitude at an altitude of 125-140 m above sea level and spreads over an area of 1,62,568 Acres (Technical report on Lal-Suhanra Biosphere Reserve, 2005).

The study area is one of the hottest and the driest regions in Pakistan with mean annual temperatures of 27.5°C whereas average monthly temperature for summer and winter may fluctuate between 35.5 to 18°C. The hottest months are June and July with average maximum temperature of 46°C some times beats 50°C. On the contrary the coldest months are December and January, where temperature may falls up to 7°C and scarcely touches the freezing point.

Average daily radiations on horizontal surface (H′) strike with the average intensity of 14.67 mJ m^{-2} in winter and 22.34 mJ m^{-2} in summer, ranges between 11.14 mJ m^{-2} in October to 24.24 mJ m^{-2} in May (Sukhara *et al*., 1986). Wind direction is predominant from South-Western in Summer and North-Eastern in Winter, Monthly average wind speed ranges between 9.5 KPH in January to 20 KPH in July with burning temperatures causing abrasive effects on tender branches and leaves of desert vegetation. High speed summer winds may cause frequent sand dune shifting that results in the burial of dwarf vegetation of the area. Mean annual precipitation fluctuates between 100 to 250 mm, the major portion of which is received during July-September. On the whole sympathetic conditions prevail that favors the vegetation growth (Sukhara *et al*., 1993).

The soil of the study area is of transported type, has been instigated from two main types of parent material that is Clayey alluvium and Aeolian sands. It fluctuates in texture from sandy to sandy loam to loamy sand. The soils are calcareous and saline-sodic, with low amount of organic matter, high pH and electric conductivity values (Akram *et al*., 1986).

The phytosociological studies under same climatic sphere of influence are mainly determined by physical features i.e., soils, releve and topography. Very few studies have been reported on the ecology of vegetation from Lal-Suhanra Biosphere Reserve i.e., Hameed *et al*.

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(2002), Arshad *et al.* (2002) and Kahlown *et al.* (2005). Present study is aimed to provide data on physiognomy and analytical characteristics of vegetation. We also hypothesized that the heterogeneity of soil chemical composition is more determining factor to shape up the natural plant communities of the area comparing to the climate. It is hoped that the present study will help the plant scientists in establishing programs for rehabilitation of degraded habitats.

MATERIALS AND METHODS

Site selection: Three diverse study sites were selected at different locations in the vicinity of Lal-Suhanra Biosphere Reserve. Sites were allocated at reasonable distances based upon subjective differences of physiognomy, vegetation type, topography, floristic composition, soil conditions and ethic intrusion. At each study site one plot of 500×500 m (250000 m^2) was demarcated. The first and third study sites were located at RD 65 inside the enclosure No.4 (8 km^2) while the second study site was situated at Moza Harnanwala in old demarcated open desert area almost 3 km South from Chak No. 33 B.C. (West) and 4.5 km towards North from enclosure No. 4.

The general vegetation of the first site was patchy dominated by grasses like *Ochthochloa compressa* and *Cymbopogon jwarancusa*, while other associated species were *Fagonia cretica* and *Salsola baryosma*. Topographically this site consisted of level ground with prominent white saline patches. The site was legally prohibited to free grazing but little disturbance caused by a herd of 80 black bucks and Chinkara. Natural desert conditions were prevailing without any anthropogenic disturbance where natural fauna and flora of the area was multiplying on the account of natural resources of the territory.

The second site was located outside the enclosed area about 6 km on the West of desert branch canal at Moza Harnanwala and was partially irrigated. The site was dominated by *Launaea nudicaulis*, *Aerva persica* and *Cymbopogon jwarancusa* present as a codominant while other associated plant species were *Cenchrus ciliaris*, *Crotalaria burhia*, *Euphorbia prostrata*, *Polygonum plebjem*, *Conyza ambigua* and *Leptadenia pyrotchnica*. The site was freely open to livestock and ethnic intervention. High grazing pressure had altered the vegetation, dominated from palatable to non-palatable plant species that could easily be observed from the species composition of the area which were left by the livestock due to non palatability. Small inter-dunal clayey flats were interrupted by small sand dunes up to 0.5-2.0 m high. Cutting of woody species for burning purposes and overgrazing have caused the serious destruction to the natural habitat. This lead the soil bare thus subjecting to erosion by high speed summer winds.

The third study site was also present inside the enclosure No.4 (8 km) at RD 65, but about 1.5 km South to the site No. I. The site was selected based upon the difference in topography and floristic composition to that of other two sites. The soil was sandy and dominated by thick vegetation of a perennial grass called *Lasiurus scindicus*, other associated plant species were *Ochthochloa compressa*, *Eragrostis japonica*, *Cenchrus ciliaris*, *Euphorbia prostrara* and *Trianthema triquetra* etc. The soil of the area was sandy with light brown color as seen under the magnifying glass. Cutting of any plant species was strictly restricted and illegal.

Data collection: Data on vegetation was recorded during March-April 2005 in the selected sites at Lal-Suhanra Biosphere Reserve, which was the period of maximum plant species growth and diversity. The vegetation was studied by rapid and frequently used quadrate method (Braun-Blanquet, 1932; Chuland and Moody, 1993; Choudhry and Khan, 2002) for attaining quantitative information about the composition and structure of plant communities. The cover of each species was estimated keeping in view the structural composition of vegetation (shrubs and grasses) the size of the quadrate (5 x 5m) was kept constant at all the study sites due to nature of vegetation growth form. Fifteen randomly placed quadrates were sampled at each demarcated site, for the quantitative estimation of phytosociological attributes such as frequency and density while cover was estimated by applying (ten line-intersects randomly placed) line-intersect method (Canfield, 1940). Each species encountered was enlisted and all individuals of all species were counted while plant samples were collected for Herbarium. Species were identified following Flora of Pakistan (Nasir and Ali, 1990).

Statistical analyses of vegetation: The data recorded on response variables i.e., density, cover and frequency of each species was estimated to their relative scales (Cox, 1967; Williems, 1982; Mashaly, 2001) and summed to give importance values (IVI) as follows:

Response variables

Frequency: Within the quadrates, the frequency was calculated on the basis of presence or absence of each target species.

Percent frequency:

It is frequency of one species as a percent of total plant frequency and was calculated as:

$$\% \text{ frequency} = \frac{\text{No. of quadrates where species occurs}}{\text{Total number of quadrate}} \times 100$$

Percent relative frequency:

The relative frequency was calculated by the formula:

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species.}} \times 100$$

Density: The density was calculated by the formula:

$$\text{i) Density} = \frac{\text{Number of plants of a certain species}}{\text{Total area sampled}}$$

Percent relative density:

It is the density of one species as a percent of total plant density.

$$\text{ii) Relative density} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

Cover: The cover of each plant species was calculated by the formula:

$$\text{i) Cover} = \frac{\text{Total area covered by a species}}{\text{Total area sampled}}$$

Percent relative cover

Like relative frequency and relative density, gives a better indication of the importance of a species than does the absolute value, was calculated as given below.

$$\text{ii) Relative cover} = \frac{\text{Cover of a species}}{\text{Total cover of all species}} \times 100$$

Importance Value Index (IVI): Importance value for each species has been calculated after calculating ,relative phytoecological attributes i.e., % relative density, % relative cover and % relative frequency, as given in the formula:

IVI = R. density + R. cover + R. frequency.

Where IVI = Importance Value Index.

Ecological indices

Shannon Wiener's Biodiversity Index (H′): It was calculated as given by Shannon-Wiener (1949).

$$H' = -\Sigma (Pi \ln Pi)$$

Where Σ = Summation sign

Pi = ni/N = Proportion of individuals belonging to each species to total number of individuals in the sample.

ni = Importance value of each species

N = Total of importance values

lnPi = Natural logarithm of Pi (base n)

Species richness (d): It was calculated as given by Margalof (1958)

$$d = (S\text{-}1)/\log N$$

Where S = Number of species

and N = Number of total individuals

Species evenness (e): It was calculated as given by Pielou (1966).

$$e = H' /\log S$$

Where H' = Shannon index, S = Number of species.

Soil sampling: Ten soil samples were collected from each study site up to 30 cm depth. Those samples were mixed thoroughly and sieved from 2 mm sieve after drying in shade for two days. The composite soil sample from each site was divided into three sub-samples. The laboratory procedures for soil chemical composition were carried out at the soil analytical laboratory of Chemistry department, The Islamia University of Bahawalpur. All the soils' chemical analyses were conducted according to the standard soil testing procedures of Soil Survey of Pakistan Lahore, Bulletin # 14 (Khan and Rafiq, 1980).

RESULTS

Floristic piece of music: Fourty-four diverse plant species belonging to nineteen families were found to be growing at selected study sites, of which Poaceae contributed the largest proportion of vegetation with 9 different, grass species. The second largest family was Chenopodiaceae with 5 plant species. Zygophyllaceae and Azoaceae had equal number of plant species i.e. 4. Rest of the families comprised of less than four plant species in the total studied vegetation (Table 1).

Table 1: Summary of floristic composition at all the study sites

Family	Plant species
1. Aizoaceae	*Gisekia pharnaceoides* Linn.
	Portula castrum Linn.
	Trianthema triquetra Willd.
2. Amaranthaceae	*Aerva persica* (Vahi) Cuf.
3. Asclapiadaceae	*Callotropis procera* R.Br.
	Leptadenia pyrotechnica Forssk
4. Boraginaceae	*Arnebia hispidissima* D.C.
	Heliotropium strigosum Willd.
5. Brassicaceae	*Farsetia hamiltonii* Royale.
6. Chenopodiaceae	*Chenopodium album* Linn.
	Chenopodium morale Linn.
	Haloxylon recurveum B.ex, Boiss.
	Salsola baryosma (Shult) Dardy.
	Suaeda fruticosa (L.) Forssk.
7. Compositeae	*Conyza ambigua* D.C.
	Launaea nudicaulis (L.) Hook.f.
	Launaea residifolia (L.) O.Kuntze.
8. Convolvulaceae	*Cressa cretica* (L.)
9. Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.
10. Cyperaceae	*Cyperus rotundus* (L.)
11. Euphorbiaceae	*Chrozophora plicata* (L.) Jones.
	Euphorbia prostrata Alt.
12. Papilionaceae	*Alhagi maurorum* Fisch.
	Crotalaria burhia Ham.Ex.Bantham.
13. Poaceae	*Aristida hystricula* (Edgew)
	Eragrostis japanica (Thumb)
	Cenchrus biflorus Roxb
	Cenchrus ciliaris Linn.
	Cymbopogon jawarancusa (Jones) schult
	Lasiurus scindicus Henrard
	Ochthochloa compressa (Forsskal.)Hilu.
	Saccharum bengalense (Retz)
	Sporobolus ioclados (Nees ex.Trin)
14. Polygonaceae	*Calligonum polygonoides* (L.)
	Polygonum plebjum (L.)
15. Solanaceae	*Solanum nigrum* (L.)
	Withania somnifera (L.)Dunal
16. Tamaricaceae	*Tamarix aphylla* (L.)
17. Tiliaceae	*Corchorus depressus* (L.) Stocks
18. Primulacea	*Anagallus arvensis* (L.)
19. Zygophyllaceae	*Fagonia cretica* (L.)
	Peganum harmala (L.)
	Tribulus longipetalis (Viv.)
	Tribulus terrestris (L.)

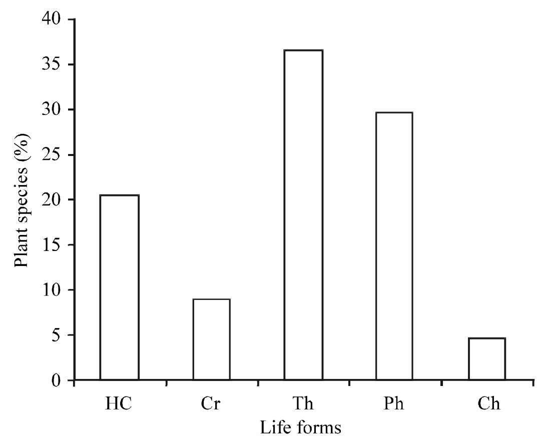

Fig. 1: Floristic life-form spectrum of all the plant species encountered at all the study sites. HC = Hemi-Cryptophytes, Cr = Cryptophytes, Th = Therophytes, Ph = Phanerophytes, Ch = Chemephytes

Biological continuum: Vegetation was chiefly composed of Therophytes (36.36%) while Phanerophytes had the second largest proportion (29.54%) in the total sampled vegetation. On the other hand Hemi-cryptophytes had the third position (20.45%) and lesser portion is shared by Cryptophytes (9.09%) and Chamaephytes (4.54%) in the floristic life-form spectrum (Fig. 1).

Absolute structural statistics: It is clear from the Table 2 that among grasses the highest average density (5768.88 ha^{-1}) and cover (3698.74 $m^2 ha^{-1}$) are estimated for the *Lasiurus scindicus*, followed by *Ochthochloa compressa* and *Cymbopogon jwarancusa* with average density of 4888.88 ha^{-1} and average cover 732.61 $m^2 ha^{-1}$, respectively. The lowest values for average density and cover are calculated for the *Cenchrus biflorus*. On the other hand among herbs maximum average density and cover has been calculated for *Lanuaea nudicaulis*. In the case of shrubs and bushes *Aerva persica* attained the highest position for average cover and density per hectare while minimum values for the same parameters are shown by the *Farsetia hemiltonii* (Table 2).

Relative phytoecological facts: The results for the relative phytosociological attributes are presented in Table 3. These results depict that *Ochthochloa compressa* had the highest relative density per hectare (37.6%) at the study site- I followed by *Cymbopogon jwarancusaa* with 35.38% relative density per hectare. On the other hand *Launaea nudicaulis* with 23.21% at the study site- II and *Lasiurus scindicus* with 45.10% at the study site- III have the maximum relative densities per hectare. The maximum values for relative cover 30.05% was estimated for the *Cymbopogon jwarancusa* at study site- 1, however, at the study sites- II and III *Aerva persica* (20.64%) and *Lasiurus scindicus* (92.24) had the enhanced values for relative cover per hectare. In the case of relative frequency *Cymbopogon jwarancusa* (20.0%) at site- I, *Aerva persica* (11.96%) at site- II and *Lasiurus scindicus* (15.46%) at sit- III were found more frequent as compared to the other plant species encountered at their respective sites. A number of plant species were restricted to a minimum relative frequency value of 0.12% confined at site-II and site-III, with no deposit beneath 1.66% relative frequency at first study site (Table 3).

Importance Value Indices (IVI): Three plant communities were recognized on the bases of highest Importance Value Index (IVI) viz: 1st-*Ochthochloa-Cymbopogon* community

Table 2: Summary of absolute (Structural) Phytosociological data of all plant species at the study sites

Plant species	Average density ha^{-1}	Maximum density ha^{-1}	Minimum density ha^{-1}	Average cover/ha(m^2)	Maximum cover/ha(m^2)	Minimum cover/ha(m^2)
Grasses						
Aristida hystricula	266.66	320.00	213.33	4.22	6.04	2.41
Cenchrus biflorus	26.66	26.66	26.66	0.11	0.11	0.11
Cenchrus ciliaris	2399.99	2773.33	2026.66	223.44	262.88	184.00
Cymbopogon jawarancusa	4159.99	7813.33	106.66	732.61	1503.28	9.06
Cyperus rotundus	400.00	400.00	400.00	3.46	3.46	3.46
Eragrostis japanica	2053.32	5786.66	26.66	35.62	102.42	0.20
Lasiurus scindicus	5768.88	16720.00	186.66	3698.74	10734.24	2.52
Ochthochloa compressa	4888.88	8320.00	426.66	596.98	1349.49	54.65
Saccharum bengalense	213.33	213.33	213.33	197.24	197.24	197.24
Sporobolus ioclados	93.33	186.66	80.00	5.50	8.50	2.51
Herbs						
Anagallus arvensis	53.33	53.33	53.33	0.41	0.41	0.41
Arnebia hispidissima	453.33	453.33	453.33	20.49	20.49	20.49
Chenopodium album	80.00	80.00	80.00	1.18	1.18	1.18
Chenopodium morale	26.66	26.66	26.66	0.32	0.32	0.32
Chrozophora plicata	32.00	32.00	32.00	7.25	7.25	7.25
Citrullus colocynthis	26.66	26.66	26.66	1.24	1.24	1.24
Conyza ambigua	1493.33	1493.33	1493.33	38.82	38.82	38.82
Corchorus depressus	26.66	26.66	26.66	0.11	0.11	0.11
Cressa cretica	26.66	26.66	26.66	0.01	0.01	0.01
Euphorbia prostrate	1866.66	1893.33	1840.00	22.67	27.30	18.05
Farsetia hamiltonii	26.66	26.66	26.66	1.57	1.57	1.57
Gisekia pharnaceoides	26.66	26.66	26.66	1.30	1.30	1.30
Heliotropium strigosum	506.66	506.66	506.66	3.59	3.59	3.59
Launaea nudicaulis	2195.53	6426.66	26.66	167.93	500.82	0.64
Launaea residifolia	213.33	213.33	213.33	12.66	12.66	12.66
Polygonum plebjum	1253.33	1253.33	1253.33	101.74	101.74	101.74
Portula castrum	53.33	53.33	53.33	0.13	0.13	0.13
Solanum nigrum	80.00	80.00	80.00	2.10	2.10	2.10
Tribulus longipetalis	133.33	133.33	133.33	3.20	3.20	3.20
Tribulus terrestris	551.10	320.00	26.66	2.73	6.42	0.32
Trienthema triquetra	2080.00	2080.00	2080.00	12.48	12.48	12.48
Withania somnifera	26.66	26.66	26.66	0.2	0.20	0.20
Shrubs and Bushes						
Aerva persica	1199.99	3173.33	53.33	290.45	811.09	3.14
Alhagi maurorum	446.66	720.00	213.33	29.57	54.33	4.82
Calligonum polygonoides	146.66	186.66	106.66	42.96	68.33	17.598
Callotropis procera	146.66	160.00	133.33	99.67	157.13	42.20
Crotalaria burhia	573.33	1093.33	53.33	124.90	243.92	5.88
Fagonia cretica	946.66	1866.66	26.66	655.82	1310.58	1.05
Farsetia hamiltonii	26.66	26.66	26.66	1.57	1.57	1.57
Haloxylon recurveum	279.99	453.33	106.66	20.84	35.66	6.02
Leptadenia pyrotechnica	173.33	320.00	26.66	112.96	223.71	2.21
Peganum harmala	80.00	80.00	80.00	0.62	0.62	0.62
Salsola baryosma	1920.00	1920.00	1920.00	576.74	576.74	576.74
Suaeda fruticosa	453.33	560.00	346.66	94.71	125.88	63.54
Trees						
Tamarix aphylla	80.00	80.00	80.00	129.76	129.76	129.76

at Site- I, 2nd- *Launaea -Aerva* community at Site- II and 3rd- *Lasiurus scindicus* community at Site-III. It is perceptible from the outcome of our results that at Site-I, *Ochthochloa compressa* occupies primary pose with IVI value of 86.31 followed by *Cymbopogon jawarencusa*, *Fagonia cretica* and *Salsola baryosma* having importance values of 82.36, 49.65, 30.22 correspondingly. The rock bottom IVI cost publicized by *Eragrostis japonica* and *Tribulus terrestris* i.e. 1.78. On the contrary at study Site-II , the uppermost importance value is represented by *Launaea nudicaulas* i.e. 47 along with *Aerva persica* as a second-dominant having 44.07 IVI. *Cymbopogon jawarencusa* appeared as a third associated species with 41.61 IVI. The lowest position on the hierarchy of importance values is occupied by *Withania somnifera* with 0.12 IVI merely. The third study site was conquered by *Lasiurus scindicus* with importance value of 152.82. The other associated species were *Ochthochloa compressa* and *Eragrostis japonica* having importance values of 30.63 and 29.88, respectively. Whereas three plant species *Cressa cretica*, *Farsetia hamiltonii* and *Cenchrus biflorus* had the lowest charge of 1.11 IVI (Fig. 2).

Table 3: Summary of relative phytoecological data for the study sites at Lalsuhanra Biosphere Reserve Bahawalpur

Plant species	Relative density			Relative cover			Relative frequency		
	Site- I	Site- II	Site- III	Site- I	Site- II	Site- III	Site- I	Site- II	Site- III
Gisekia pharnaceoides	-	0.09	-	-	0.03	-	-	0.12	-
Portula castrum	-	0.19	-	-	0.03	-	-	0.12	-
Trianthema triquetra	-	-	5.61	-	-	0.10	-	-	5.51
Aerva persica	1.69	11.46	0.14	1.14	20.64	0.02	3.32	11.96	2.06
Callotropis procera	0.72	0.48	-	0.84	3.99	-	1.66	2.56	-
Leptadenia pyrotechnica	0.12	1.15	-	0.44	5.69	-	1.66	3.41	-
Arnebia hispidissima	-	1.63	-	-	0.52	-	-	1.70	-
Heliotropium strigosum	-	-	1.36	-	-	0.03	-	-	4.12
Farsetia hamiltonii	-	-	0.07	-	-	0.01	-	-	1.03
Chenopodium album	-	0.28	-	-	0.03	-	-	1.70	-
Chenopodium morale	-	0.09	-	-	0.08	-	-	1.70	-
Haloxylon recurveum	0.48	1.63	-	0.12	0.90	-	6.65	5.12	-
Salsola baryosma	8.69	-	-	11.53	-	-	10.00	-	-
Suaeda fruticosa	-	2.02	0.93	-	3.20	0.54	-	4.27	6.18
Conyza ambigua	-	5.39	-	-	0.98	-	-	4.27	-
Launaea nudicaulis	0.60	23.21	0.07	0.04	12.74	0.05	1.66	11.11	1.03
Launaea residifolia	-	0.77	-	-	0.32	-	-	0.12	-
Cressa cretica	-	-	0.07	-	-	0.01	-	-	1.03
Citrullus colocynthis	-	0.09	-	-	0.03	-	-	0.12	-
Cyperus rotundus	-	1.44	-	-	-	-	-	0.12	-
Chrozophora plicata	-	1.15	-	-	0.18	-	-	1.70	-
Euphorbia prostrate	-	6.84	4.96	0.08	0.15	-	-	5.12	6.18
Alhagi maurorum	0.96	2.60	-	0.09	1.38	-	1.67	1.70	-
Crotalaria burhia	-	3.94	0.14	0.04	6.20	0.05	-	6.83	2.06
Aristida hystricula	0.96	-	0.86	-	-	0.05	1.66	-	4.12
Eragrostis japanica	0.12	1.25	15.61	0.004	0.10	0.88	1.66	0.12	13.39
Cenchrus biflorus	-	-	0.07	-	-	0.01	-	-	1.03
Cenchrus ciliaris	-	7.32	7.84	-	4.68	2.25	-	6.83	12.37
Cymbopogon jawarancusa	35.38	16.47	0.28	30.05	17.44	0.07	20.00	7.69	4.12
Lasiurus scindicus	0.84	1.44	45.10	0.05	9.15	92.24	3.32	2.56	15.46
Ochthochloa compressa	37.68	1.54	15.97	26.98	1.39	3.32	21.6	2.56	11.34
Saccharum bengalense	-	0.77	-	-	5.02	-	-	1.70	-
Sporobolus ioclados	0.84	-	0.21	0.17	-	0.02	1.66	-	2.06
Calligonum polygonoides	-	0.67	0.28	-	1.73	0.01	-	2.56	3.09
Polygnum plebjum	-	4.52	-	-	2.58	-	-	4.27	-
Solaum nigrum	0.36	-	-	0.42	-	-	1.66	-	-
Withania somnifera	-	0.02	-	-	0.05	-	-	0.12	-
Tamarix aphylla	0.36	-	-	2.59	-	-	1.66	-	-
Corchorus depressus	0.12	-	-	0.02	-	-	1.66	-	-
Anagallus arvensis-	0.19	-	-	0.10	-	-	-	0.12	-
Fagonia cretica	8.45	-	0.07	26.20	-	0.09	15.00	-	1.03
Peganum harmala	0.36	-	-	0.01	-	-	1.58	-	-
Tribulus longipetalis	-	-	0.35	-	-	0.02	-	-	2.06
Tribulus terrestris	0.12	1.15	0.28	0.06	0.16	0.01	1.66	1.70	1.03

Ecological indices: The study Site- II i.e., *Ochthochloa-Cymbopogon* community was found to be the most tentative with reference to the probability of pronouncement of a given plant species as depicted by the highest biodiversity index value of 2.88 followed by site-I and site-III with 1.93 and 0.054 correspondingly. The *Launaea-Aerva*-community found as the topmost with respect to species richness as shown by the principal value of 4.17, however, *Lasiurus scindicus* community occupies the second position with value of 2.73, followed by *Ochthochloa-Cymbopogon* community with the minimum value of species richness i.e., 2.67. Present results for evenness showed that the plant species in *Launaea-Aerva* community were uniformly distributed as compared to *Lasiurus scindicus* community. The vegetation at the *Ochthochloa-Cymbopogon* community was patchy with the lowest evenness value of 0.017 (Table 4).

Geodermal analyses: The results depict that the soils at the study sites were much heterogeneous, whereas the texture of soils ranged from sandy to sandy loam to loamy sand. Electric Conductivity was one of the most diverse parameters for the soil chemical composition ranging from 1.12-4.06 ds m^{-1} with much variability from site to site. The soils were calcareous, saline sodic with alkaline

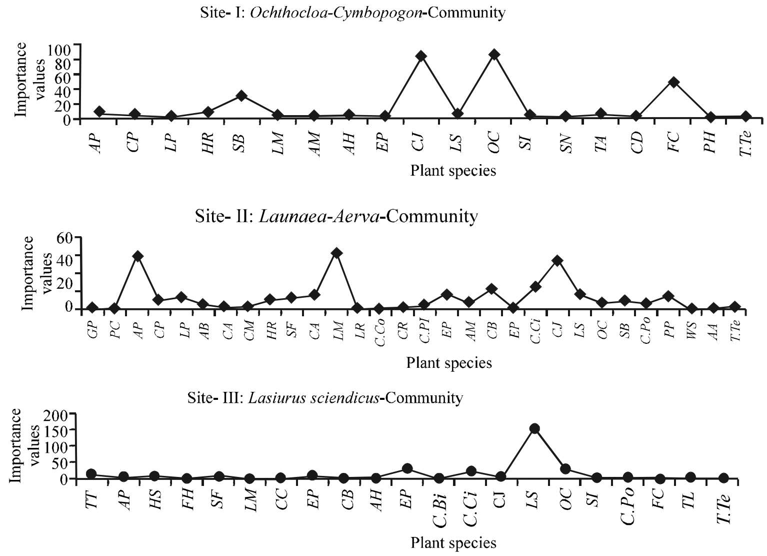

Fig. 2: The importance values and plant communities at the study sites at the Lal-Suhanra Biosphere Reserve. Plant legends: *Gisekia pharnaceoides* = GP, *Portula castrum* = PC, *Trianthema triquetra* = TT, *Aerva persica* = AP, *Callotropis procera* = CP, *Leptadenia pyrotechnica* = LP, *Arnebia hispidissima* = AB, *Heliotropium strigosum* = HS, *Farsetia hamiltonii* = FH, *Chenopodium album* = CA, *Chenopodium morale* = CM, *Haloxylon recurveum* = HR, *Salsola baryosma* = SB, *Suaeda fruticosa* = SF, *Conyza ambigua* = CA, *Launaea nudicaulis* = LN, *Launaea residifolia* = LR, *Cressa cretica* = CC, *Citrullus colocynthis* = CCo, *Cyperus rotundus* = CR, *Chrozophora plicata* = CPl, *Euphorbia prostrata* = EP, *Alhagi maurorum* = AM, *Crotalaria burhia* = CB, *Aristida hystricula* = AH, *Eragrostis japanica* = EP, *Cenchrus biflorus* = CB, *Cenchrus ciliaris* = CCi, *Cymbopogon jawarancusa* = CJ, *Lasiurus scindicus* = LS, *Ochthochloa compressa* = OC, *Saccharum bengalense* = SBe, *Sporobolus ioclados* = SI, *Calligonum polygonoides* = CPo, *Polygonum plebjum* = PP, *Solanum nigrum* = SN, *Withania somnifera*= WS, *Tamarix aphylla* = TA, *Corchorus depressus* = CD, *Anagallus arvensis* = AA, *Fagonia cretica* = FC, *Peganum harmala* = PH, *Tribulus longipetalis* = TL, *Tribulus terrestris* = TT

Table 4: Species number and ecological indices of the plant communities established at all study sites

Communities	Total No. of species	Biodiversity index $H'=-\Sigma$ (Pi ln Pi)	Species richness index d = (S-1)/log N	Species evenness e = H'/log S
Ochthochloa-Cymbopogon	19	1.936	2.678	0.657
Launaea-Aerva	30	2.883	4.175	0.847
Lasiurus scindicus	21	0.054	2.763	0.017

Table 5: Physico-chemical analysis of soils from three study sites in Lal-Suhanra Biosphere Reserve, Bahawalpur, Pakistan

	Soil texture			Soluble cations ($meq\ L^{-1}$)			Soluble anions ($meq\ L^{-1}$)									
Sites	Silt	Clay	Sand	Ca^{++} and Mg^{++}	Na^{+}	K^{+}	CO_3^{-2} and HCO_3^{-}	Cl^{-}	Total N (%)	Available P (%)	Organic matter (%)	WHC (%)	Moisture (%)	pH (1:2 H_2O)	EC ($dS\ m^{-1}$)	Textural classes
1	13.8	16.4	69.8	3.62	2.15	1.23	2.48	11.70	0.14	8.9	0.33	38	4.66	8.2	4.06	Loamy-sand
2	8.2	9.0	82.8	2.00	0.26	0.06	2.52	2.40	0.08	2.6	0.31	34	3.33	8.4	2.14	Sandy-loam
3	0.8	2.4	96.8	4.06	1.36	0.29	1.78	1.80	0.07	1.7	1.34	28	2.66	8.6	1.12	Sandy

nature having low amount of organic matter, the typical feature of arid region. Water holding capacity ranges between 28 to 38 % resulting in the low moisture contents. Total amount of available Phosphorus (P) and Nitrogen (N) were the highest at site- I, but lowest at the site- III. Calcium and Magnesium found to be the major soluble Cations with the highest proportion of 4.06 meq L^{-1} at site- III and sodium at study site- I. The concentrations of Carbonates and Bicarbonates were not significantly variable among the sites, however, Chloride (11.7 meq L^{-1}) was major soluble Anions at site-1 and lowest at site- III (Table 5).The Pearson Mount correlations between physicochemical parameters are prearranged in Table 6, which kept up a correspondence to the positive and

Table 6: Correlation matrix of soil variables. Pearson moment correlation(r) on the means (n = 14) at three study sites

Soil variables	Sand	Silt	Clay	Ca^{+2} and Mg^{+2}	Na+ (meq L^{-1})	K+ (meq L^{-1})	CO_3^{-2} and HCO_3^-	Cl^- (meq L^{-1})	N total	P (ppm)	OM (%)	WHC (%)	Mois (%)	pH
Silt	-0.99*													
Clay	0.99*	-0.99*												
Ca^{+2} and Mg^{+2} (meq L^{-1})	-0.22	0.28	0.17											
Na+	0.05	0.10	0.003	-0.98										
K+	0.74	0.70	0.77	0.48	0.63									
CO^{-2} +$HCO3^-$	-0.85	0.88	0.82	-0.70	0.56	0.28								
Cl^-	-0.88	0.85	-0.90	0.26	-0.42	0.97	0.50							
Total N (%)	-0.91	0.89	0.93	0.18	-0.35	0.95	0.57	0.99*						
Phosphorus (ppm)	-0.90	0.88	0.92	0.20	-0.37	0.95	0.55	0.99*	1.00**					
Organic matter (%)	0.86	-0.89	-0.84	0.67	-0.53	-0.31	-1.00**	-0.53	-0.59	-0.58				
Water holding capacity (%)	-0.99*	0.99*	0.99*	-0.31	0.14	0.67	0.89	0.83	0.87	0.86	-0.91			
Moisture (%)	-0.02	0.08	-0.02	-0.97	1.00**	-0.65	0.54	-0.45	-0.38	-0.39	-0.51	0.11		
pH (1:2 H_2O)	0.85	-0.82	0.87	-0.31	0.47	-0.98	-0.45	-0.99*	-0.99*	-0.99*	0.48	-0.80	0.50	
EC	-0.98	0.96	0.989*	-0.029	-0.14	0.86	0.73	0.95	0.97	0.97	-0.75	0.95	-0.17	-0.94

Abbreviations :- OM = Organic Matter, WHC = Water Holding Capacity, Mois = Moisture. ** Correlation is significant at the 0.01 level i.e., Positive between, Sodium + Moisture and Phosphorus + Nitrogen Negative between, Carbonate and Bicarbonate and Organic matter. * Correlation is significant at the 0.05 level i.e., Positive between, WHC + Silt + Clay, Total Nitrogen + Chloride and Phosphorus + Chloride Negative between, Sand + Silt, pH + Chloride, pH + Total Nitrogen and pH + Phosphorus

negative significant correlations among various soil factors. For example Na^+, P^+, total N and Cl^- were positively correlated while CO_3^{-2} and HCO_3^-, Organic mater and pH were negatively correlated either at 0.01 and 0.05 levels.

DISCUSSION

Plants can be grouped in life-form classes based on their similarities in structure and function (Mueller-Dombois and Ellenberg, 1974). A life-form is characterized by plant adaptation to certain ecological conditions (Mera *et al*., 1999). Life- form study is an important part of vegetation system that is ranked next to floristic composition (Cain, 1950). In the present study we use Raunkiaer's system to classify the life-forms of plants found at all the study sites (Raunkiaer, 1934).

In our life-from spectra the most represented class is the Therophyte which represents the characteristic of desert vegetation. Under the desert condition moisture regime plays an important role in the lifecycle of Therothytes. Thus lifecycle is modified according to the availability of favorable season and mostly confined to the rainy season (Khan and Chaudhry, 2001). On the other hand perennial species like *Cymbopogon jwarancusa*, *Cenchrus ciliaris* and *Lasiurus scindicus* are included in Hemicryptophytes. The parenating buds of these grasses are just below the soil surface (Vogl, 1974), thus can withstand the high grazing pressure and remained dormant during the unfavorable season (Chaudhry and Iqbal, 1999) until the reach of next rainy season.

The leading dominant technique (Rafique and Khan, 1983) disclosed the ecological affinities among some of the dominant species. Among grasses *Lasicurus scindicus*, *Ochthochloa compressa*, *Cymbopogon jwarancusa* and *Cenchrus ciliaris* are with high average density per hectare as compared to the other encountered species and are considered as dominants (Table 2). Infact, grasses were found growing at all the study sites (Table 4) showing their wider ecological amplitude in terms of soil and environmental adaptations. However, they have different growth patterns. Both *Lasiurus scindicus* and *Cenchrus ciliarus* are mostly found growing in the sandy flats with less salinity as compared to the *Ochthocloa compressa* and *Cymbopogon jwarancusa* (Table 5 and 6). Further more *Lasiurus scindicus* has relatively deep root system as compared to other perennial grasses found in the study area. It's roots can be deducted up to the depth of one and half meter in soil, suggesting efficient usage of episodic resources and drought tolerance (Akram *et al*., 1986). This may be the one reason that this grass also shows the highest average cover per hectare.

Among herbs *Launaea nudicaulis* has the maximum density and cover per hectare followed by *Euphorbia prostrata*. Both of these herbs are ephemerals and their population prospers when there is plenty of soil and air water. Such high correlation among precipitation and vegetation cover has been commonly observed in semiarid landscapes (Khan and Chaudhry, 2001), Gebauer *et al*. (2002), Schwinning *et al*. (2003) concluded that minimum daily air temperatures control the transition between the vegetation communities of the Mojave and Great Basin deserts, based on relatively limited spatial/temporal data acquired at local scales.

In the case of shrubs and bushes the halophyte *Salsola baryosma* attained the first position with highest average density per hectare (1920.00) followed by *Aerva persica* with 1199.99 ha^{-1}. average density, while the highest value for the average cover of 655.82 m^2 ha^{-1}

was estimated for the *Fagonia cretica*. It may be noted that these bushes have very low economic value from the grazing point of view and usually found to be growing at degraded habitats. *Salsola baryosma* and *Fagonia cretica* were found to be growing on the salt patches in the study area showing their high salt tolerant capability.

Present study with regard to the vegetation found at a particular site represent somewhat different picture from the overall ecological parameters taken into consideration. There were obvious differences in the floristic and edaphic factors while the climatic conditions do not vary from site to site. It depicts that soil heterogeneity may play an important role in the establishment of plant communities other than climatic factors. Table- 6 shows the pearson moment correlation (r) between the various soil variables which clearly depicts that soils were heterogeneous in their chemical composition at the study sites. Soil properties vary on spatial and temporal scales (Campbell and Grime, 1989). In dune soils, for example, the annual variation in pH has been shown to be around one pH unit (Troelstra *et al*., 1990). Spatial variability of soil parameters is neither random nor stationary (Webster, 2000) and is mostly caused by geological and climatic processes. Also biological processes and the vegetation influence spatial variability in soil parameters as much or more than climatic processes (Goderya, 1998). In natural areas, in general, variability of soil nutrients like N, P, or K has been shown to increase with spatial scale (Beckett and Webster, 1971). On a larger scale, vegetation composition of sand dunes is closely associated with soil development. Decreasing species diversity of vegetation is likely to explain decreasing variability in soil pH (Isermann, 2005).

Soil pH and moisture as well as biomass or productivity are very important factors for explaining species richness (Schaffers, 2002).It is likely that there is a correlation between species diversity and pH in nutrient poor sands (Isermsnn, 2005).In our investigations there is not significant difference of pH among the three study sites as shown by Physico-chemical analyses (Table 5) i.e., only of 0.2 pH units but there are considerable differences between species diversity, richness and evenness (Table 4). We figure out that the changing values of salinity from site to site may be responsible for controling the floristic composition of three different plant communities recognized at the surveyed sites.

We estimated the importance values (IVI) of the plant species residing at different studied sites to assertion the dominance or co-dominance among the plant species at a particular site. The IVI infect depicts the importance of a particular plant species and its role controlling the plant community. The plant species with highest IVI values usually have better chances to survive and most adoptive to the area under consideration (Choudhry and Khan, 2002).

Three plant communities were recognized on the basis of most enhanced values of IVI (Fig. 2). According to our results *Ochthochloa compressa* was recognized as a leading dominant at Site- 1 with admiration to importance values followed by *Cymbopogon jawarencusa* as a next widespread deposit in conjunction with *Fagonia cretica* and *Salsola baryosma*. At this point *Eragrostis japonica*, *Tribulus terretris*, *Corchorus depressuus* and *Leptadenia pyrotechnica* were top secrets as the exceptional plant life. The soil at this site was predominantly loamy sand with relatively high water holding capacity, available P, total N and salinity level in comparison to the other two sites. Such edaphic nature seemed to support the growth of *Ochthochloa compressa* and *Cymbopogon jwarancusa*. The rich growth of *Ochthochloa compressa* may be attributed to its salt loving nature. Correspondingly at study site- 2, the overriding vegetation was represented by *Launaea nudicaulis* along with *Aerva persica* as a subsequent prevailing plant. *Cymbopogon jawarencusa* appeared as a third dominant, while *Cenchrus ciliaris*, *Crotalaria burhia*, *Lasiurus scindicus*, *Polygonum plebjem*, *Conyza ambigua* and *Leptadinia pyrotechnica* were present as allied plant species. The lowest position on the pecking order of importance values was occupied by *Withania somnifera*. This site was situated in the fenced area of RD-65 (enclosure No. 4) and the open grazing has not been practiced. Infect this enclosure had been in use as breeding site for deer mainly Black Buck (nearly 80 in number), therefore, we could not visualize any kind of grazing effect on vegetation how ever topographically this site was quite diverse in having small dunes with sandy loam soils (Table 5). In fact *Launaea nudicaulis* is a small prostrate herb with beautiful yellow colour flowers on erect stems. It was found abundantly growing on salt patches in the study area. It appeared that this herb can survive well on the soils with moderate fertility and high salt contents. Yet the third study site was dominated by an exceedingly palatable perennial grass, *Lasiurus scindicus*, other associated plant species were *Ochthochloa compressa*, *Eragrostis japonica*, *Cenchrus ciliaris*, *Euphorbia prostrata* and *Trianthema triquetra*. The highest IVI value of *Lasiurus scindius* at this site showed that this plant species can grow well due to its deep root system even when the soil has low nutritional value. Another important factor is that the roots of this grass form sand sheath on its surface that may help it to seek more nutrients as compared to other shallow rooted grasses encountered at this site.

The diversity of the ecosystem studied was calculated using the concept of entropy in Shannon-Wiener index. This index has the monotonicity property and accounts for abundance and rarity of species (Roy *et al*., 2004).The diversity of the species and their distribution (evenness) is taken into consideration in this index ($H' = -\Sigma$ (Pi ln Pi)) was found having different values at all the three study sites: at site-2 (*Launaea-Aerva* community) the index with the highest value (2.883) showed the highest entropy of the system with respect to the presence of largest number of rare species on the basis of IVI values (Fig. 2). This site was existed near the rural settlement due to which it was subjected to livestock grazing. It had been reported that cattle grazing increase plant species richness of most species trait groups in mesic semi-natural grasslands (Pykala, 2004). Species richness, biodiversity and evenness were higher in the grazed area than in the enclosure (Sites 1 and 3) (Table 4). These findings confirm previous reports for other grasslands in Uruguay (Rodgriguez *et al*., 2003), the Flooding Pampa (Rusch and Oesterheld, 1997, world wide (Milchunas and Launenroth, 1993) and Uruguayan grassland (Altesor *et al*., 2005). There was also a shift of dominant species from palatable to non-palatable between enclosed to open (grazed) study sites respectively. These functional changes within dominant grass species have been observed between other grasslands of Uruguay (Rodgriguez *et al*., 2003; Altesor *et al*., 2005) and Pakistan (Choudhry and Khan, 2002).

In short the results of our study suggests that the governing factors of this typical type of Arid Zone plant life are seemed to be the physical ,chemical and biological environmental factors existing at the study area along with morphological and physiological adaptations of the vegetation to cope with established ecological state of affairs.

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