Pak. J. Bot. 8 (2): 133—149 1976

A PHYTOSOCIOLOGICAL STUDY OF GADAP AREA, SOUTHERN SIND, PAKISTAN

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Abstract

Twenty-two stands in Gadap area, Southern Sind were sampled quantitatively and soil samples were analysed physically and chemically. The leading dominant technique revealed the ecological affinities among the dominant species. Diversity analysis of leading dominant groups showed minimum diversity for *Cordia gharaf* group and maximum for *Euphorbia caducifolia* group. Species richness was mainly responsible for changes in general diversity whereas the equitability component was insignificant. Cover per acre (standing crop) and density per acre of perennial species were found to be inversely related to diversity measures.

Objective classification of vegetation disclosed three community types. Community type 1, confined to sandy plains, is dominated by *Pteropyrum olivieri*, *Cordia gharaf* and *Capparis decidua*, and appears to be correlated with soils having moderate depth, relatively high organic matter, poor maximum water holding capacity (MWHC), calcium carbonate and exchangeable potassium. Community type 2, restricted to dry stream beds, is principally constituted by *Euphorbia caducifolia*. *Rhazya stricta* and *Prosopis cineraria*; it seems to be supported by shallow soils which are poor in organic matter and MWHC, and contain high proportion of calcium carbonate. Community type 3 which abounds on sand dunes, is chiefly composed of *Prosopis cineraria*. *Lycium depressum* and *Leptadenia pyrotechnica* which are capable of build'ng phytogenic sand mounds; this community is associated with soils having relatively high MWHC, pH and exchangeable sodium and potassium.

Introduction

Published quantitative phytosociological studies on desert and semi-desert vegetation of Pakistan are few and mostly confined to Sind. Repp (1962) gave a quantitative description of the vegetation of certain areas of Sind and Punjab and gave recommendations on the land use separately for the different localities. Hussain (1964) analyzed the vegetation of Nagar-Parkar and categorised it into four formations, which were found to be associated with characteristic physiographic conditions. Chaudhri and Chuttar (1966) gave a quantitative account of the vegetation of Thar desert and discussed the dynamic relations of communities. Qadir *et al* (1966) carried out a phytosociological survey of Karachi University campus, recognizing six distinct plant communities and correlated the diversity of vegetation with the edaphic conditions. Hussain (1970) studied the ecology of coastal dunes in Karachi and neighbourhood, and related the successional sequence with the enviornmental gradient. Karim (1970) developed an objective classification of the vairous plant communities of the coastal swamps in Karachi and its vicinity and corresponded the vegetational groups with the environmental characteristics. Shaukat and Qadir (1971) investigated the phytosciology of calcarious hills around Karachi and demonstrated a potential continuity in vegetation with the aid of an indirect gradient analysis. Shaukat and Hussain (1972) analyzed the vegetation in and around the stream and that of the hills of Khadeji-fall area and described the hydrosere and lithosers succession.

The major objectives of this investigation were (1) to study the composition and structural characteristics of the vegetation, particularly the degree of community organization (2) to asertain the relationship between phyosgraphic factors and stand composition and (3) to appraise the feasibility of the application of objective classification to desert vegetation.

Description of the Area

Gadap, a small village, is located at about 25 miles north-east of Karachi, at latitude 25° '9° N and longitude 67°' 13° E An extensive area of nearly 200 square miles around the village was surveyed. The climate and geology of the area has been described by Pithawala (1946), hence only a brief description of these follows:

The parental rock in the area comprises of Kirthar formation (middle to upper eocine). Calcareous shale and limestone outcrops in the form of parallel or sub-parallel ridges extend on the western and northern sides of the village. Apart from ridges the area is generally a flat country. Flat plains also exist in between the ridges. The plain is dissected by a number of dry streams (runnels) having beds constituted by sandy soil. In between the western ridges and the village the area is occupied by sand dunes.

The climate of the area has been referred to by Chaudhri (1961) as subtropical maritime desert. The bioclimate of the area determined by Holdrige's (1947) system falls into the category of tropical desert bush formation. The average annual rainfall is 7.75 inches, out of which 6.16 inches are received during the monsoon period lasting from June to September. Summers are quite hot; the hottest month being June with a mean monthly temperature of about 36°C. Winter season is very short, lasting from November to January. The coldest month is January with an average monthly temperature of about 19°C. Relative humidity is high. It is higher in summer than the winter. The lowest relative humidity occurs in January (35%) and the highest in September (75%). Strong winds are a chracteristic feature of the area.

Material and Methods

a) *Field methods:*

A reconnaissance study preceded the sampling of vegetation. All samples were located more or less subjectively. Criteria for the selection of a stand were adequate size (5 acres or more) of the sample area, visual homogeneity of vegetation and physiography, and as far as possible lack of disturbance (e.g. cutting, fire, grazing or browsing). Twenty-two stands, which met these requirements, were sampled during December, 1974 to February, 1975, using point-centered quarter method of Cottam and Curtis (1956). The sampling was restricted to perennial plants, whereas only the 'presence' of annual plants was recored. In addition the area was surveyed again in July and October, 1976 after the monsoon rains so as to make the presence list of annuals and ephimerals more comprehensive. Soil depth was noted and soils were collected at 3 different sites in a stand. The three sub-samples were pooled to obtain a composite soil sample. Nomenclature of plants in this paper follows that of Stewart (1972). Wherever, subsequent nomenclatural changes have been promulgated (in the underprint Flora of Pakistan), the valid names are followed.

b) *Soil analysis:*

The composite soil samples were air dried and passed through a 2 mm sieve in order to separate gravel. The portion finer than 2 mm was used for chemical and physical determinations. The analysis of soil texture was carried out by pipette method (USDA, 1951). Maximum water holding capacity (MWHC) was determined according to the method described by Keen (1920). Total organic matter was estimated by the loss-on-ignition method, after making allowance for carbonate and clay content (Jackson, 1958). Amount of soil calcium carbonate was ascertained by the method of Qadir *et al* (1966) and pH was measured by EIL (Model 23A) glass electrode pH meter after preparing the samples according to Peech *et al.*, (1947). Exchangable potassium and sodium were evaluated by the flame-photometric method outlined by Burriel-Marti *et al.* (1957). At least duplicate determinations were made on each composite soil sample.

c) *Vegetational analysis:*

The following analytic attributes were calculated for each stand: the relative and percentage frequency; density per acre and relative density; total cover per acre and relative coverage of each perennial species. The relative values for all the three measures were combined by summation into a single importance value index (I.V.I.) following the practice of Curtis and McIntosh (1951).

The relationship among the dominant species encountered in the survey was examined in a general way by employing the method of leading dominants developed by Brown and Curtis (1952). A table was prepared in which I.V.I. of the species in stands dominated by the leading dominants (i.e. the species possessing the highest I.V.I. in a stand) were arranged on the basis of perceived sociological relationships among the species.

Species diversity of the leading dominant groups were compared and the structural characteristics of vegetation (viz. coverage and density per acre) were related to diversity measures. The general species diversity combines two components of diversity: (1) the richness component which is variously expressed by simple ratios between number of species and total number of individuals (2) equitability or evenness of allotment of individuals among the species (Peet, 1974). The general diversity was ascertained by the popular Shannon-Wiener information function $H = -\sum pi \log_2 pi$ (Margalef, 1957), where H is general diversity and $pi = ni/N$ is the proportion of individuals belonging to the ith to the total number of individuals in the sample. This index is problely the most appropriate as has been shown in a computer simulation (Fager, 1972) and can be confirmed with field data (Heip and Engels, 1974). The species richness was calculated as $d = S/\sqrt{N}$ (Menhinick, 1964) where d is species richness and S and N are total number of species and total number of individuals respectively. Equitability was expressed as the ratio of observed diversity to maximal diversity: $E = H/H\ max$ (Pielou, 1969), where E equals the equitability, H equals the observed general diversity and $H_{max} = -S\ (1\frac{1}{S}\ \log_2 \frac{1}{S}) = \log_2 S$ equals the maximum species diversity.

The objective classification was accomplished by the method described by Mountford (1962), which is a simple form of agglomerative cluster analysis. A Q-type similarity matrix of $\frac{1}{2}n\ (n-1) = 231$ entries was prepared for which similarities between pairs of stands were computed by Czekanowski's (1913) coefficient of similarity $= SI = \frac{2\sum \min (Xi, Yi.)}{\sum.(Xi + Yi)}$ where (Xi equals the I.V.I. of the species belonging to one stand and Yi is this measure for the other stand being compared.

Agglomeration proceeds as follows: the two most similar samples (stands) i.e. those with the highest similarity, are grouped together and their relation to each other sample calculated as the mean of the index of each of the pair with the other sample. Thus if A and B have the highest index of similarity the index of a set A.B. with C is SI (AC) + SI (BC)/2. Similarly an index between two sets (say A.B.C. and D.E.) would be obtained as SI (AD) + SI(AE)+ SI(BD)+........SI (CE)/6. This procedure allows for the construction of dendrogram which shows at what distance (percentage similarity) certain points are linked.

RESULTS

a) *Vegetational composition and structure.*

The data on phytosociological analysis are summarized in Tables 1,2 and 3. The number of perennials encountered in the study area is twenty-nine, (Table 1) and that of annuals is fifty four (Table 3). The presence values show the number of stands out of the total of 22 in which each species occurred (Table 1), whereas the second column shows the values of arithmetic mean of the I.V.I. for the species in those stands in which the species occurred. A high presence coupled with a high average I.V.I. indicates that the species occurs in most of the stands and is an important constituent in those stands. Most of the species are of minor importance and only five, *Prosopis cineraria*, *Pteropyrum olivieri*, *Cordia gharaf*, *Euphorbia caducifolia* and *Capparis decidua* ever attained the position of leading dominant. *Prosopis cineraria* is evidently the most widespread and important species. *Pteropyrum olivieri* is also widely distributed, and with the exception of a few stands occurs as a dominant species in sandy plain. Though *Zizyphus nummularia* occurs ubiquitously in the area surveyed yet it is represented moderately in various stands, which is reflected by its medium value of mean I.V.I. Likewise *Indigofera oblongifolia* is also widely distributed but with slightly lower I.V.I. Both *Zizyphus nummularia* and *Indigofera oblongifolia* are relatively more conspicuous on sand dunes in comparison to other habitats. *Euphorbia caducifolia* is almost restricted to dry stream beds and has a high average I.V.I. indicating that it is one of the dominant species in the stands in which it is present. *Rhazya stricta* is also represented with high I.V I. in dry stream beds but also occurred in some stands of sand dunes.

Density per acre and cover per acre of perennial species (Table 2) which represent the structural characteristics of the vegetation indicate that plant cover is somewhat scanty and the vegetation is sparse. *Prosopis cineraria* has highest average density and cover per acre typifying it as a dominant species in the study area. *Pteropyrum olivieri* has second highest value of average density owing to its profusion in sandy plains and dry stream beds. *Eurohorbia caducifolia* shows second highest average cover, although it occurred only in three stand indicating its dominating role in such stands.

Of the 54 annuals recorded only four viz. *Cenchrus setigerus*. *C. pennisetiformis*, *Digera muricata* and *Zygoyhyllum simplex* occurred in at least 50% of the stands (Table 32). Annuals that occurred in at least 25% of the stands include: *Aristida adscensions*, *Eragrostis ciliaris*, *Rhynchosia minima*, *Tribulus terrestris*, *Tragus roxburgii*, *Cyamopsis tetragonoloba* and *Indigofera oblongifolia*. Forty-three annuals were found to be present in less than 25% of the stands.

TABLE 1 Summary of relative phytosociological data

SPECIES	Presence No. of stards	Average I.V.I.	Maximum I.V.I.	Minimum I.V.I.	No. of stards 1st dominant	No. of stands 2nd dominant	No. of stands 3rd dominant
Prosopis cineraria (L.) Druce	22	78.018	152.546	20.838	14	2	3
Zizyphus nummularia (Burm f.) Whight & Arn.	22	20.791	39.931	5.481	—	2	—
Indigofera oblongifolia Forsk.	20	11.494	26.720	3.800	—	—	1
Pteropyrum olivieri Jaub & Spach.	19	41.752	147.875	8.142	3	5	2
Capparis decidua (Forssk.) Edgew.	15	21.516	58.415	5.989	1	1	—
Cassia italica (Mill.) Lam. ex F.W. Andr	15	21.653	42.180	3.693	—	2	3
Commiphora wightii (Arnott.) Bhandari	15	19.094	38.068	4.611	—	—	1
Leptadenia pyrotechnica (Forssk.) Dcne.	15	24.340	57.175	4.119	—	3	3
Lycium depressum Stocks.	15	35.832	57.445	14.989	—	3	6
Blepharis sindica Stocks ex.T. Anders.	12	12.937	28.097	3.894	—	—	—
Cordia gharaf (Forssk.) Ehren. ex. Asch	10	37.175	72.580	6.431	2	2	2
Cassia holosericea Fresn.	10	16.618	31.873	7.786	—	—	—
Fagonia arabica Linn.	10	5.532	7.889	3.615	—	—	—
Gymnosporia senegalensis (Lam.) Loes.	[illegible]	13.047	19.273	4.392	—	—	—
Grewia tenax (Forssk.) Aschers and Schweinf.	6	17.267	27.589	9.972	—	—	—
Prosopis juliflora Swartz.	6	21.397	33.117	8.943	—	—	—
Rhazya stricta Dcne.	6	28.840	34.427	5.253	—	2	1
Calotropis procera (Willd.) R. Br	4	6.261	9.274	4.287	—	—	—
Euphorbia caducifolia Haines	4	42.109	69.797	16.331	2	—	—
Euphorbia hirta Linn.	3	8.530	12.929	4.177	—	—	—
Heliotropium ophiglossum Boiss.	3	7.279	13.645	4.016	—	—	—
Rhynchosia pulverulenta Stocks	3	7.337	13.259	4.305	—	—	—
Periploca aphylla Dcne.	2	10.674	11.250	10.098	—	—	—
Salivia santolinifolia Boiss.	2	3.657	3.664	3.650	—	—	—
Acacia nilotica (Linn.) Delile.	1	6.145	6.145	6.145	—	—	—
Aerva persica (Burm.f.) Merrill.	1	4.050	4.050	4.050	—	—	—
Ruellia patula Jacq.	1	3.901	3.901	3.901	—	—	—
Launaea procumbens (Roxb.) Rammaya and Rajgopal	1	8.636	8.636	8.636	—	—	—
Salvadora oleoides Dcne.	1	4.625	4.526	4.526	—	—	—

TABLE 2 Summary of Absolute (structural) Phytosociological Data

Species	Average density/ acre	Maximum density/ acre	Minimum density/ acre	Average cover/ acre (sq.ft.)	Maximum cover/ acre(sq.ft.)	Minimum cover/ acre(sq.ft.)
Prosopis cineraria (L.) Druce	77.092	156.551	10.955	674.162	1514.630	17.509
Pteropyrum olivieri Jaub. & Spach	67.123	165.789	8 217	138.016	1006.837	6.633
Cordia gharaf (Forssk.) Ehren. ex. Asch.	45.975	107.206	3.811	324.070	785.134	30.346
Lycium depressum Stocks.	41.680	107.551	21.913	149.643	398.223	25.649
Rhazya stricta Dcne.	34.213	55.978	3.800	50.929	82.814	15.594
Cassia italica (Mill.) Lam. ex. F.W.Andr.	32.610	74.175	2.708	14.119	54.859	0.519
Cassia holosericia Fresn.	32.435	74.157	11.040	11.791	67.029	0.077
Zizyphus nummularia (Burm. f.) Whight & Arn	24.490	58.583	3.558	142.579	945.904	12.267
Blepharis sindica Stocks. ex. T. Anders.	24.349	91.928	5.520	0.511	1.908	0.003
Leptadenia pyrotechnica (Forssk.) Dcne.	23.625	45.177	4.384	112.197	324.704	3.891
Indigofera oblongifolia Forssk.	17.087	47.983	2.738	25.941	191.644	1.885
Commiphora wightii (Arnott.) Bhandari	16.615	38.624	2.738	231.115	737.772	7.633
Grewia tenax (Forssk.) Aschers & Schweinf	16.020	24.883	5.645	94.062	284.405	23.913
Capparis decidua (Forssk.) Edgew	15.457	36.749	4.145	240.689	808.602	34.675
Rhynchosinpulverulenta) Stocks	14.369	27.589	7.525	19.324	37.170	6.804
Gymnosporia senegalensis (Lam.) Loes.	11.714	23.991	3.811	78.850	194.199	30.119
Prosopis juliflora Swartz.	11.678	18.374	5.890	309.605	651.122	58.026
Euphorbia hirta Linn.	11.651	16.642	6.078	0.282	0.384	0.128
Launaea procumpens (Roxb.) Rammaya & Rajgopal	11.093	11.093	11.093	—	0.382	0.382
Euphorbia caducifolia Haines	10.664	16.587	4.384	653.490	1656.008	126.046
Fagonia arabica Linn.	8.755	18.374	2.738	0.645	1.747	0.323
Heliotronium ophioglossum Boiss.	6.982	11.406	3.625	6.486	12.532	2.889
Periploca aphylla Dcne.	6.885	3.293	5.477	31.494	32.023	30.965
Acacia nilotica (Linn.) Delile	5.520	5.520	5.520	—	7.479	7.479
Ruellia patula Jacq.	5.520	5.520	5.520	—	0.043	0.043
Salvadora oleoides Dcne.	5.520	5.520	5.520	—	2.144	2.114
Calotropis procera (Willd.) R. Br.	5.430	7.995	3.800	59.501	1274.498	6.195
Aerva persica (Burm.f.) Merrill.	3.558	3.558	3.558	—	2.134	2.134
Salvia santolinifolia Boiss.	3.441	4.145	2.738	0.518	0.743	0.294

TABLE 3. Presence list of annual species recorded in the survey. Occurrence in number of stands out of 22 is presented.

S. No.	Species	Presence No. of stands
1.	*Cenchrus setigerus* Vahl	20
2.	*C. pennisetiformis* Hochst. and Steud.	18
3.	*Digera muricata* (L.) Mart.	12
4.	*Zygophyllum simplex* L.	12
5.	*Aristida adscensionis* L.	10
6.	*Eragrostis ciliaris* (L.) R. Br.	9
7.	*Rhynchosia minima* (L.) DC.	9
8.	*Tribulus terrestris* L.	9
9.	*Tragus roxburgii* Panigari	8
10.	*Cyamopsis tetragonoloba* (L.) Taub.	6
11.	*Indigofera cordifolia* Heyne ex Roth	6
12.	*Achyranthes aspera* L.	5
13.	*Eragrostis pilosa* (L.) P. Beauv.	5
14.	*Indigofera hochstetteri* Baker	5
15.	*Pulicaria angustifolia* DC.	5
16.	*Amaranthus lividus* L.	4
17.	*Cleome viscosa* L.	4
18.	*Dactyloctenium aegyptium* (L.) P. Beauv.	4
19.	*Euphorbia prostrata* Ait.	4
20.	*Vigna trilobata* (L.) Verdc.	4
21.	*Portulaca oleracea* L.	4
22.	*Amaranthus viridis* L.	3
23.	*Aristida funiculata* Trin. & Rupr.	3
24.	*Corchorus trilocularis* L.	3
25.	*Helotropium subulatum* (DC) Vatake	3
26.	*Leucas urticifolia* R. Br.	3
27.	*Glinus lotoides* L.	3
28.	*Oldenlandia aspera* DC.	3
29.	*Peristrophe bicalyculata* (Retz.) Nees	3
30.	*Schweinfurthia pediceilata* (T. Anders.) Bth. Hk. f.	3
31.	*Puilcaria boissieri* Hk. f.	3
32.	*Sporobolus coromendelianus* (Retz.) Kunth	3
33.	*Aizoon canariense* L.	2
34.	*Anticharis linearis* (Bth.) Hochst. ex Aschers	2
35.	*Cassia occidentalis* L.	2
36.	*Elionurus royleanus* Nees ex A. Rich.	2
37.	*Cleome gynandra* L.	2
38.	*Indigofera linifolia* (L. f.) Retz.	2
39.	*Ipomoea sindica* (Stocks) Stapf.	2
40.	*Monosonia heliotropioides* (Cav.) Boiss.	2
41.	*Polycarpaea spicata* Wight and Arn.	2
42.	*Polygala erioptera* DC.	2
43.	*Oligochaeta ramosa* (Roxb.) Wagenitz.	1
44.	*Chrozophora obliqua* (Vahl) Juss. ex. Spreng.	1
45.	*Convolvulus arvensis* L.	1

(Table 3 *Contd*)

6.	*Corchorus tridens* L.	1
47.	*Glossonema varians* (Stocks) Bth.	1
48.	*Hibiscus intermedius* A. Rich.	1
49.	*Leucas nutans* Spreng.	1
50.	*Corbichonia decumbens* (Forssk.) Exell	1
51.	*Physalis minima* L.	1
52.	*Trichodesma africanum* var. *emplexicaule* (Roth.) Cooke	1
53.	*Vernonia cinerea* (L.) Less	1
54.	*Xanthium strumarium* L.	1

b) *Leading dominants:*

Table 4 gives the average I.V.I. of the dominant species in the stands in which a given species is the leading dominant *Petropyrum olivieri* is better represented in *Cordia gharaf* dominated group but is less conspicuous in other groups, particularly in *Euphorbia caducifolia* group in which it has very low I.V.I. *Cordia gharaf* shows relatively higher I.V.I. in stands in which *Pteropyrum alvieri* is the leading dominant and poor I.V.I. in *Prosopis cineraria* and *Eurhordia caducifolia* dominated groups. *Prosopis cineraria* appears to be better associated with *Cordia gharaf* and associated to a lesser degree with *Euophorbia caducifolia* and *Capparis decidua*. *Capparis decidua* is prominent in *Pteropyrum olivieri* dominated stands and is poorly represented in *Euphorbia caducifolia* group. *Euphorbia caducifolia*, with the exception of stands in which it is a leading dominant occurs only, among the stands surveyed, in *Prosopis cineraria* dominated stands and is completely absent elsewhere.

TABLE 4 Mean I.V.I. of species in stands in which a given species occurs as a leading dominant (number of stands in parenthesis).

Species	LEADING DOMINANT GROUPS				
	Pteropyrum olivieri (3)	Cordia gharaf (2)	Prosopis cineraria (14)	Capparis decidua (1)	Euphorbia caducifolia (2)
Pteropyrum olivieri	94.01	60.61	30.55	34.12	9.94
Cordia gharaf	53.50	67.94	18.22	37.52	0.0
Prosopis cineraria	36.31	63.19	99.43	32.11	31.13
Caparis decidua	36.74	17.66	18.51	47.09	9.68
Euphorbia caducifolia	0.0	0.0	25.11	0.0	59.10

c) *Diversity relations of leading dominant groups*

Table 5 shows mean cover per acre (standing crop) density per acre, species richness, equitability and general diversity of the 5 leading dominant groups. *Cordia gharf* and *Capparis decidua* dominated groups possess comparatively high coverage per acre whilst *Euphorbia caducifolia* dominated group has low coverage. Density per acre is highest in *Capparis decidua* dominated stand and relatively low in stands in which *Euphorbia caducifolia* or *Pteropyrum olivieri* occur as leading dominant. Species richness is maximum in *Euphorbia caducifolia* group and minimum in *Cordia gharaf* dominated stands. Same is true for equitability and general diversity. The relationships between diversity measures and coverage and density per acre are expressed in Table 6. Coverage per acre (standing crop) shows significant negative correlation with species richness, equitability and general diversity ($p<0.01$). However, values of correlation coefficient between density per acre and diversity measures though appreciable are marginally non-significant. The regression equations describing the relationship between coverage and density per acre and diversity indices appear beneath Table 6. The value for one variable given the other variable can be predicted with reasonable accuracy by these equations.

TABLE 5 Mean cover, per acre (sq. ft.), density per acre, species richness, equitability and general diversity of the leading dominant groups.

Leading dominant groups	Mean cover per acre (sq.ft.) (C_2)	Mean density per acre (D_2)	Species richness (d)	Equitability (E)	General diversity (H)
Pteropyrum olivieri	2395.33	337.07	1.463	0.219	0.746
Cordia gharaf	2589.99	448.01	1.291	0.168	0.662
Prosopis cineraria	2019.96	344.15	1.419	0.200	0.734
Capparis decidua	2579.52	551.79	1.549	0.212	0.755
Euphorbia caducifolia	987.34	206.59	2.000	0.886	1.007

TABLE 6 Relationship of coverage per acre (standing crop) and density per acre with diversity measures in terms of correlation coefficient. Regression equations for these relationships are given below the table.

Diversity measures	Coverage/acre (C_2) (sq. ft.)	Density/acre (D_2)
Species richness (d)	–0.883**	–0.621 n.s.
Equitability (E)	–0.942**	–0.729 n.s.
General = diversity(H)	–0.934**	–0.714 n.s.

$$d = 2.280 - 0.00035\ C_2\ ;\ C_2 - 5489.52 - 2185.95\ d$$
$$E = 1.245 - 0.00043\ C_2\ ;\ C_2 - 2807.21 - 2056.30\ E$$
$$H = 1.160 - 0.00018\ C_2\ ;\ C_2 - 5847.52 - 4786.02\ H$$
$$d = 2.034 - 0.00129\ D_2\ ;\ D_2 - 836.69 - 297.39\ d$$
$$E = 0.986 - 0.00172\ D_2\ ;\ D_2 - 481.17 - 307.59\ E$$
$$H = 1.052 - 0.00072\ D_2\ ;\ D_2 - 928.85 - 706.84\ H$$

TABLE 7 **Topographic and edaphic characteristics of the stands.**

Stand No	Topography	Soil depth (inches)	pH	Organic matter (%)	$CaCO_3$ (%)	Exchangeable Na (ppm)	Exchangable K (ppm)	Maximum water holding capacity (%)	Soil texture: Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
1.	Sandy plain	28	7.4	0.720	15.82	54	16	19.13	51.6	32.1	9.2	7.1
2.	,,	24	7.3	2.120	13.15	40	9	16.42	55.9	27.5	12.3	4.3
3.	,,	24	7.1	1.004	13.91	46	12	17.24	49.3	32.2	10.9	7.6
4.	,,	20	7.1	1.300	16.32	56	12	15.55	63.5	24.4	5.1	7.0
5.	,,	22	7.3	1.670	14.05	63	15	18.94	57.9	26.0	7.7	8.4
6.	,,	18	7.1	2.140	14.30	41	9	18.21	48.4	31.4	12.3	7.9
7.	,,	23	7.5	2.080	17.18	54	13	17.55	52.0	29.7	8.5	8.9
8.	,,	20	7.0	2.200	15.09	56	8	17.60	49.6	31.9	10.4	8.1
9.	Sand dune	26	7.2	0.580	14.83	42	10	26.10	53.3	14.8	17.5	14.4
10.	,,	22	7.2	0.750	13.51	60	9	17.85	55.5	25.4	9.0	10.1
11.	,,	22	7.5	2.060	18.25	66	16	14.42	72.2	16.1	6.8	4.9
12.	,,	20	7.3	1.865	16.00	55	14	17.35	55.1	30.3	9.8	4.8
13.	,,	25	8.0	2.078	18.95	91	19	23.62	48.4	24.0	15.4	12.2
14.	,,	24	8.0	2.125	20.33	79	17	20.92	52.1	29.4	8.0	10.5
15.	,,	25	7.9	2.113	18.50	76	15	19.27	47.8	35.5	11.7	5.0
16.	,,	25	7.5	1.982	14.25	65	12	20.12	53.0	28.2	11.2	7.6
17.	,,	26	8.2	1.182	23.19	95	21	21.23	48.2	30.0	31.1	8.7
18.	,,	28	8.0	0.951	19.65	90	16	18.90	56.7	28.6	10.0	4.7
19.	,,	23	7.6	1.193	15.45	59	20	19.85	50.7	29.2	12.5	7.6
20.	Dry stream bed	19	7.9	1.252	18.70	62	22	24.29	46.1	23.6	14.3	16.0
21.	,,	12	7.8	1.019	18.83	51	14	18.82	59.4	22.6	13.2	4.8
22.	,,	10	7.7	0.768	17.31	55	15	18.16	56.8	27.3	10.7	5.2

Table 8. Edaphic variable averaged for the three community types.

S. No.	Communities	Soil depth (inches)	pH	Organic matter (%)	$CaCO_3$ (%)	Maximum water holding capacity (%)	Exchangeable K (ppm)	Exchangeable Na (ppm)	Sand (%)	Silt (%)	Clay (%)
1.	Community type I	21.6	7.22	1.787	14.85	17.36	50.71	11.14	82.81	9.60	7.58
2.	Community type II	11.0	7.75	0.893	18.07	18.49	53.00	14.50	83.05	11.95	5.00
3.	Community type III	23.7	7.69	1.510	17.63	20.35	70.75	15.91	79.52	11.61	8.87

d) *Objective classification and correlation of edaphic variables with the vegetation types:*

The result of agglomerative cluster analysis is a dendrogram which shows the relationships of the stands to each other (Fig. 1). The length of each vertical line indicates the relative similarity of the stand or group of stands to the other entity with which it is combined. Thus lengths of vertical lines are inversely proportional to similarity. Community types are recognized at an arbitrary level of 40% similarity following the practice of Crawford and Wishart (1967). Three community types are detected on the basis of compositional similarity. Physiographic characteristics of all the 22 stands are presented in Table 7 and the edaphic variables are averaged for the three communities in Table 8. The three community types have the following vegetational and environmental characteristics:

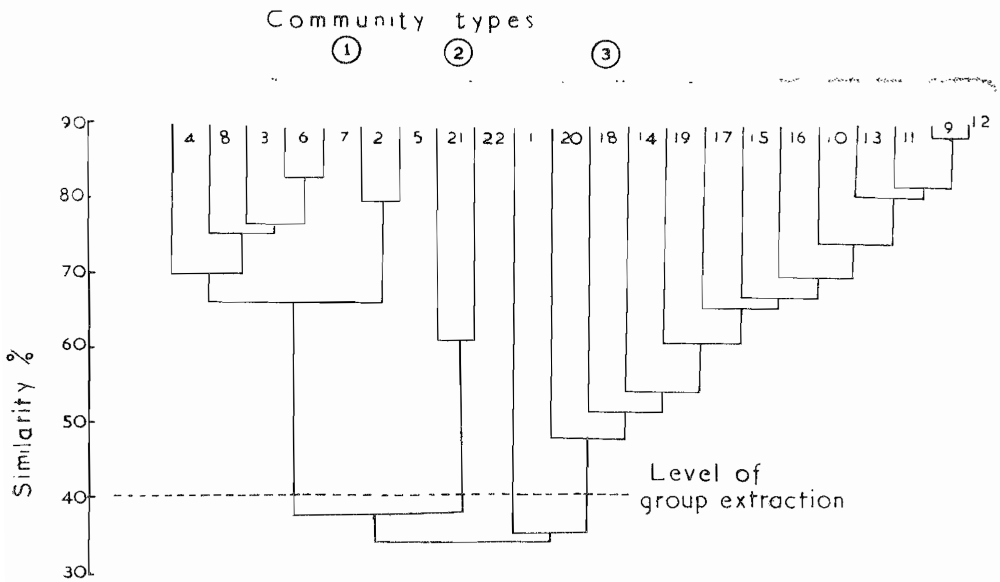

Fig. 1. Dendrogram produced by agglomerative classification of the stands from Gadap area using I. V. I. of perennial species. Stand I being compositionally intermediate between community types 1 and 3 remains secluded.

Community type 1. —This community type is confined to sandy plain. The plant growth of this habitat is dominated by *Pteropyrum olevieri*, *Cordia gharaf* and *Capparis decidua*. The principal perennial associates include *Prosopis cineraria*, *Zizyphus nummularia*, *Indigofera oblongifolia* and *Commiphora wightii* in respect of their I.V.I. None of the associate species is confined to this community type and the former two associates are better represented in community type 3. The dominants are mostly spiny and deciduous shrubs. The branches of *Capparis decidua*, however, remain green and consequently photosynthetically active throughout the year. The records of this community type include 34 annuals of which more frequent ones are *Cenchrus setigerus*, *Digera muricatal*, *Zygophyllum simplex*, *Eragrostis ciliaris*, *Tribulus terrestris* and *Indigclera cordifoia*. Annuals of lesser importance include: *Cenchrus pennisetiformis*, *Aristida abscensionis*, *Rhynchosia minima*, *Tragus roxburgii*, *Cyamopsis tetragonoloba*, *Achyranthus aspera*, *Indigofera hochstettri* and *Pulicaria angustifolia*.

This community type is associated with soils that have moderate depth and contain relatively high organic matter but have poor maximum water holding capacity (MWHC), calcium carbonate and exchangeable potassium.

Community type 2.—This community type is restricted to dry stream beds and is recognizable, in the first instance, by the exuberant growth of cactoid spurge — *Euphorbia caducifolia* which is either scarce or completely absent in other communities. Dominance of this community type is shared by *E. caducifolia. Rhazya stricta* and *Prosopis cineraria*. These are accompanied by a substantial proportion of *Lycium depressum*, *Grewia tenax*, *Pteropyrum olivieri* and *Zizyphus nummularia*. With the exception of *Rhazya stricta* and *Grewia tenax* the major perennials are armed with spines and excluding *Rhazya stricta* all are deciduous. However, the clumps of *Euphorbia caducifolia* remain green and serve as assimilatory organs throughout the year. *Prosopis cineraria* is generally a tree but here it exhibits a shrubby habit. Common annuals coexisting with the perennials are *Rhynchosia minima*. *Cleome viscosa*, *Glinus lotoides*, *Indigofera hochstetteri*, *Heliotropium subulatum*, *Leucas urticifolia*, *Pulicaria biossieri*, *Oldenlandia aspera* and *Sporobolus coromendelianus*. The microclimate created by *Euphorbia caducifolia* facilitates a profuse growth of annuals.

The soil supporting this community type is relatively shallow, poor in organic matter and MWHC but is impregnated with comparatively higher proportion of calcium carbonate.

Community type 3. – Almost all the stands of this community type are associated with sand dunes. Typically this community is dominated by perennial shrubs of *Prosopis cineraria*, *Lycium depressum* and *Leptadenia pyrotechnica*. Notable perennial associates are *Cassia obovata*, *Zizyphus nummularia*, *Pteropyrum olivieri* and *Gymnosporia senegalensis*. Excluding *Gymnosporia senegalensis*, *Cassia italica* and *Pteropyrum olivieri* the major perennial species are deciduous. Relatively lesser number of perennials are spiny in this community type in comparison to other two communities. Most of the principal shrubs are effective in collecting, building and stabilizing phytogenic sand mounds. Among the herbaceous annual flora, *Cenchrus setigerus*, *C. pennisetiformis*, *Dactyloctenium aegypticum*, *Eragrostis pilosa*, *Vigna trilobata* *Aristida funiculata* and *Corchorus trilocularis* are frequent and usually flourish in between the dunes.

The soil of this group shows relatively high MWHC, pH and exchangeable sodium and potassium and the soil depth in the stands of this community is substantially greater than that of community type 2.

Discussion

The vegetation in the surveyed area exhibits local differences owing to varied physiographic conditions. Three topographic situations, namely sandy plains, sand dunes and dry stream beds were encountered. These differ considerably in regard to micro-relief, soil-depth and other edaphic conditions related to moisture status and nutrient supply and consequently represent distinct habitats. Each habitat supports a more or less characteristic vegetation. Although there are species which are common to different habitats yet their density, frequency and coverage differ in different situations. In general, the vegetation is predominantly composed of perennial xerophytic shrubs which form the permanent framework of the stands. The annual herbaceous flora entirely comprises of summer annuals, many of which are ephemerals.

The leading dominant technique disclosed the ecological affinities among the dominant species. *Pteropyrum olivieri* and *Cordia gharaf* seem to be ecologically similar. *Capparis decidua* appears to be more closely related to *Pteropyrum olivieri* than to *Cordia gharaf*. These specific relationships have also been previously noticed by Qaiser and Qadir (1972). Typically, the above three species occur together in varied proportion as dominants on sandy plains. Although *Prosopis cineraria* is ubiquitously distributed in stands having varied leading dominants but exhibits closer ecological propinquity with *Cordia gharaf*. Association between these two species, according to Qadir *et al* (1966), prevails on sandy plains where soil possesses good structure, relatively high magnesium content and medium depth. Some of these observations are consistent with the present findings. Evidently, *Euphorbia caducifolia* is negatively associated (*sensu* Williams and Lambert, 1959) with *Pteropyrum olivieri*, *Cordia gharaf* and *Capparis decidua* and slightly positively associated with *Prosopis cineraria*. Hussain and Qadir (1970) recorded the negative association of *Euphorbia caducifolia* with *Pteropyrum olivieri* and *Cordia gharaf* but noticed a better growth and abundance of *Euphorbia caducifolia* in association with *Capparis decidua*. In Gadap area *Euphorbia caducifolia* is almost restricted to dry stream beds owing presumably due to competitive influence of species better adpated to prevailing environmental conditions of sandy plains and sand dunes. This perhaps accounts for the observed negative associations of this plant.

Species diversity is considered to be an important attribute of community organization and allows comparison of structural characteristics of communities (Hairston, 1959, 1964). It is often related to community dynamics, stability, productivity, integration, evolution, niche structure and competition (Poole, 1974; Pielou, 1976). The idea of displacement of one species through competition with others is of prime importance in this connection (Hardin, 1960; Whittaker, 1965). Communities are conceived by some to be quite highly organized entities, and the species within them the result of evolution in close association and competition. The recent studies on diversity usually consider in addition to species richness, the equitability component of general diversity (Tramer, 1969; Johnson *et al.*, 1975). These components of diversity were taken into account in the present study. However, the degree of relationship between cover per acre (standing crop) and density per acre with the components of diversity and general diversity was more or less of the same order. Such a situation is apprehensible in the light of the fact that a strong positive correlation existed among the general diversity and its components (Khairi, 1974). Thus the evenness of allotment of individuals among the species has no significant bearing on general diversity which is almost solely governed by species richness.

Among the leading dominant groups the highest species diversity was recorded in the *Euphorbia caducifolia* group. This may be attributed to the maximum co-occurrence of shrub species of various habitats in the dry stream beds which in turn is ascribable to less austere moisture regime owing to the seasonal collection of the run-off water in these runnels. Furthermore, a number of other species are favoured by the microclimatic conditions created by *Euphorbia caducifolia*. Both coverage per acre (standing crop) and density per acre were found to be negatively correlated with the diversity measures. Similarly, McNaughtan (1968) and Auclair and Goff (1971) found stand productivity and basal area to bear inverse relationship with species diversity. A tentative explanation for such a relationship is that competition closely regulates the number of species capable of coexisting in comparatively more productive environments.

The soils in the area studied are characteristically azonal, calcarious, coarse-textured and being geologically young are not differentiated into well-defined horizons. However, the soils of the three communities vary to a certain extent in physical and chemical lineaments. The soils of community type 1 and 2, which may be designated as Pteropyrum — Cordia — Capparis community and Euphorbia — Rhazya — Prosopis community respectively, are alluvial in nature. But the soil of community type 3, which can be referred to as Prosopis – Leptadenia – Lycium community, are predominately eolian where wind-blown sand is deposited over the waterborne deposits. The high calcium carbonate content of soils is due to the fact that these are derived from calcarious rocks. In general, organic matter content is low, first because of the open plant cover, secondly because of intense insolation that causes rapid oxidation and thirdly due to partial dispersion of vegetable waste by winds and gales. The alkaline nature of soil reaction is evidently due to preponderance of calcium carbonate. The poor clay content of soils coupled with excess of calcium ions impoverish the exchangeable potassium.

Kassas and Imam (1959) pointed out two sets of factors which render difficulties in classifying desert communities. The first problem is philosophical and expressed by the controversy that prevails between 'organismic' and 'indivisualistic' schools of thought — differing basically in the recognition of vegetational units (cf. Becking, 1957: Shimwel, 1971). Since both of these concepts were developed in relation to the vegetation of temperate regions, they should be applied to desert vegetation with caution. The organismic school holds that communities are integrated units with dicrete boundaries and hence amenable to classification. Whereas, proponents of individualistic school assert that communities are not integrated units but collections of populations that require the same environmental conditions — consequently any recognition of discrete entities is purely arbitrary.

The second problem of classification is a practical one. The difficulties encountered in recognizing units of desert vegetation are due to its peculiar features. The desert vegetation is generally characterized by the openness of stands, mixture of dissimilar life-forms, scarcity of true subordinate plants, low species diversity, and recurrence of the same few species with the repetition of a particular habitat. Owing to simplicity of composition, the entrance or exist of a single major species effectuates a striking change in the physiognomy of the vegetation (Shreve, 1951: Kassas, 1953).

The resolution of philosophical problem can be approached by considering the objective of the study. The main purpose of present investigation was to relate the vegetational composition of Gadap area to habitat conditions. This purpose of study was reasonably accomplished by objective classification, since (a) it is free from the premises of organismic or individualistic concepts (b) it is more effective and efficient than the traditional classification (c) it employs relatively less skilled labour (d) it identifies and uses natural discontinuities more consistently and (e) allows extraction of precise and ecologically more meaningful groups without the element of personal bias.

The practical difficulties that render the classification of desert communities difficult are also substantially eleviated, without the loss of ecological information, by adapting an objective classificatory procedure. The traditional classification system of Braun-Blanquet (1932) is a popular choice for large surveys where the primary aim is to provide a broad conceptual framework as an aid towards grasping the overall vegetational environmental pattern. This method has been applied with some success for the study of the units of desert vegetation (Kassas and Imam, 1959). However, the Braun-Blanquet system suffers from a number of serious drawbacks mostly associated with the qualitative or subjective recording of phytosociological attributes (cf. Poore, 1955; Becking, 1957).

In the present study, quantitative analysis was restricted to perennial vegetation which forms the bulk of plant cover, and the proportion of annual species was not taken into account for the purpose of vegetational classification. The growth, abundance and variety of annuals or ephimerals is chiefly regulated by rainfall, which in this region is low and erratic causing marked seasonal and annual fluctuations, in their composition. Consequently the inclusion of annual flora in the classification of desert vegetation is unsafe. The technique employed for numerical classification being polythetic (taking into account the quantitative parameters of different (perennial) species), therefore, successfully overcomes the practical difficulties imposed upon by the peculiarities of desert vegetation.

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