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MULTIVARIATE APPROACHES TO THE ANALYSIS OF THE VEGETATION-ENVIRONMENTAL COMPLEX OF GHARO, DHABEJI AND MANGHUPIR INDUSTRIAL AREAS.

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Abstract

Twenty stands from 4 localities viz., Gharo. Dhabeji Shujaabad and Manghupir industrial areas were sampled quantitatively and the soil samples from various stands were analysed physically and chemically. Using dis-similarity matrix of species composition a three-dimensional phytosociological ordination was constructed.

The three-dimensional environmental ordination was constructed on the basis of integrated response to various soil factors. Thus the moisture gradient, calcicolous gradient and silt-clay gradient served as the axes of the ordination.

The study of the spatial pattern of 10 important species in the phytosociological as well as environmental ordination showed that no two species were identically distributed and each species followed a more or less continuous distribution pattern.

A three-dimensional species constellation was built in which continuous distribution of species was apparent and clustering of species was not perceptible.

Introduction

The vegetation of southern Sind exhibits considerable local variation and a complex vegetational pattern in response to diverse topographic and edaphic features. The vegetation of certain topographic situations like calcarious hills, sand dunes and some sandy plains has been investigated (Qadir, *et al*. 1966; Shaukat & Qadir, 1971; Shaukat, *et al*. 1976). However, the vegetation of plains, that constitute the major portion of the area, and which shows considerable local compositional variation, has not been thoroughly investigated so as to build a comprehensive picture of the vegetational pattern of southern Sind.

Four localities were selected for the study viz., Dhabeji, Gharo, Shjuabad and Monghupir where certain portions have been allocated for the establishment of industries. Due to industrial expansion natural communities are being taken over by semi-natural or disturbed communities, but the sites away from the industrial areas support pristine vegetation which is amenable to ecological analysis. The later investigations, after the industrial expansion, would presumably allow a comparison of the vegetation, environment and their interrelationships with the ecological conditions that prevail at present.

This investigation was undertaken with the following objectives in mind: 1) to investigate the pattern of vegetational composition of the areas, 2) to study the

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ecological relationships among species, 3) to ascertain the relationship of the vegetational pattern with the environmental complex, 4) to compare the behavior and efficiency (in phytosociological context) of some ordination approaches using data collected under actual field conditions of the selected localities.

Climate of the study area

The records of climatic conditions prevailing in the localities surveyed may be derived from the meteorological station situated at Drigh Road, not more than 21 kilometers away from the various stands sampled. According to Koppen's (1936) system, the climate of the area belongs to the type BWh. The bio-climate of the area, determined by Holdrige's (1947) system, comes in the category of tropical desert bush formation. The average annual rain fall is 19.68cm, out of which 15.64cm, are received during 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 in the area is generally high. It is higher in summer than the winter. The lowest relative humidity occurs in January (35%) and highest in September (75%). Strong winds are a characteristic feature of this region.

Geology and geography of the area

Dhabeji-Gharo-Shujaabad Area: The area covered approximately 25900 hectares, lying on the north and south sides of the National Highway, between the 17th and 36th mile posts, east of Karachi. It is bounded by limestone outcrops on the north-eastern sides and by the Arabian sea and coastal dunes on the southern side while the intensely cultivated alluvial plains of the Malir River lie close to the western boundary. An account of the geology of the area is given by Siddiqui (1953). The deposits overlying the upper pleistocene outwash gravels, and locally by recent sands. The limestone in the north are probably part of the Gaj series laid down in the lower Miocene. At this time, the area was part of a shallow in a warm sea, and was subjected to intermittent uplift. Sand, clay and shell limestone of Manchar series were deposited in upper Miocene and lower Pleistocene, prior to complete marine recession. In the late pleistocene times, there was further uplift. Arid weathering and erosion of the limestone hills to the north produced debris which was transported by sporadic streams and sheet flooding. The outwash sands and gravels form the surface material over most of the area.

Monghupir area: The village of Monghupir is situated at about 16 kilometers north of Karachi city. The outcrops in the area are those of Nari formation which belong to oligocene period; they are constituted by limestone, sand stone or shale.

Methods

(o) *Field methods:*

A reconnaissance study preceeded 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 lack of disturbance of vegetation (e.g. cutting, grazing or browsing). Twenty stands which met these requirements were selected and sampled during November, 1973 to February, 1974.

The stands were sampled by point centered quarter method (Cotton & Curtis, 1956). A complete presence list of rare species (those not encountered with in the sampling points) was prepared. Soil depth was noted and soil collected at three different sites in a stand. The three sub-samples of soils were pooled to obtain a composite soil sample.

The identification of plants and their nomenclature was followed after Stewart (1972).

Soil analysis

The composite soil samples were air-dried and passed through a 2mm sieve in order to separate gravel. The portion finer than 2 mm was used for physical and chemical determinations. The analysis of soil texture was carried out by pipette method (USDA, 1951). Maximum water holding capacity (MWCH) was determined according to the method described by Keen (1931). Humus content of soil was measured by treating 10g oven dried soil with 10ml. of 30% H_2O_2; the loss in weight represented the quantity of humus (USDA, 1951). Soil calcium carbonate was determined by treating 10g of soil with 10% HCl until the effervescence ceased; the $CaCl_2$ thus formed was filtered and the loss in weight gave the approximate $CaCO_3$ content of soil (Qadir *et al*, 1966). Soil pH was measured by ELL (Model 23A) glass electrode pH meter after preparing the samples according to Peech *et al* (1947). For the determination of exchangable phosphate the colorimetric method of Fogg & Wilkinson (1958) was employed and exchangable pottassium and sodium were evaluated by the flame-photometric methods outlined by Peech & English (1944) and Burriel-Marti & Ramirez-Munoz (1957). Duplicate determination were made on each composite soil sample.

Statistical Methods

(a) *Phytosociological attributes:*

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

(b) *Vegetational ordintion:*

Vegetational samples were arranged in a three-dimensional ordination according to the method outlined by Bray & Curtis (1957) incorporating the modifications described by Beals (1960, 1965). The ordination was based on similarity coefficinet adduced by Czekanowski (1913). Out of the twenty stands sampled 6 were excluded from the vegetational ordination study since they were associated with water-logged and saline soils and exhibited marshy flora which was remarkably distinct from that of the rest of the 14 stands. The total number of comparisons was $\frac{1}{2}n(n-1)=91$. Each index value was subtracted from a maximum of 100 to obtain an inverse value relative to the theoretical maximum. These inverse values (dissimilarity values) were used to order stands along the X,Y and Z axes following the practice of Beals (1965).

(c) *Species ordination:*

The method adopted for the construction of species ordination was that of Gittins (1965), which is an R-type modification of the Bray & Curtis technique. Only those species were choosen for this ordination which occurred in at least 6 stands. There were 19 species which met this criterion and provided an R-type similarity matrix of 171 entries. The dissimilarity was obtained by subtracting the similarity value from a theoretical maximum of 100. The internal structure of the matrix was portrayed in a three-dimensional configuration in accordance with Beals (1965). Stands of water-logged sites were excluded from species ordination study for the reasons adduced earlier.

(d) *Environmental ordination:*

For the establishment of an environmental ordination the method of Bray & Curtis as modiled by Monk (1965, 1966) was employed. The X axis position of the stands were determined by their similarity in MWHC (%) and soil depth. The similarity in soil pH and percentage of calcium carbonate was measured to locate the stand position on Y axis while the Z axis location of stands was determined on the basis of similarity in combined percentage of silt and clay.

The data for all the above mentioned edaphic variables were transformed into relative values. This was accomplished by expressing the data from each stand as a percentage of the highest value that was found among the 20 stands surveyed. The relative values were employed in the computation of the coefficient of similarity. Thus three separate matrices of similarity were prepared, each consisting of 1/2n (n—1)=190 entries. The dissimilarity values were obtained, as mentioned earlier. Method of positioning of stands on the axes was based on Beals (1965). The X, Y and Z axes represented synthetic moisture gradient, calcicolous gradient and silt-clay gradient respectively.

Results

(a) *The vegetational characteristics:*

The presence values given in the first column of Table 1 indicate the number of stands out of the total of 20 in which each species occurred. The second column is the arithmetic mean of the importance value index (Curtis & McIntosh, 1951) 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 in which it occurs.

Fifty-one species were recorded from the entire study area, of which thirty were encountered among the sampling points whereas 21 species were merely observed and were presumably rare. Most of the species were of minor importance as indicated by average IVI and only six *Euphorbia caducifolia, Prosopis cineraria, Commiphora wightii, Zizyphus nummularia. Grewia tenax* and *Fagonia arabica* were most important. Six stands revealed a substantially distinct composition from the rest of the stands; being associated with water-logged and saline soil they were dominated by halophytic plants like *Tamarix troupii, Cressa cretica* and *Aleuropus lagopoides*. However, other species like *Pulicaria hookeri, Artriplex griffithii, Cordia gharaf, Barleria acanthoides, Lycium depressum* and *Indigofera oblongifolia* were next in importance. Some species like *Capparis decidua, Acacia arabica, Panicum turgidum. Heliotropium*

TABLE 1. Summary of relative phytosociological data.

Species	Presence No. Stands	Average I.V.I.	Maximum I.V.I.	No. of stands 1st Dominant	No. of stands 2nd Dominant	No. of stands 3rd Dominant
Zizyphus nummularia (Burm.f) Wight and Arn.	14	23.33	65.57	—	2	1
Euphoribia caducifolia Haines	13	81.79	158.99	8	3	1
Prosopis cineraria (L.) Druce	13	46.23	98.89	4	3	2
Commiphora wightii (Arnott) Bhandari	13	31.61	59.15	—	4	2
Grewia tenax (Forssk.) Ehren. ex Arch.	13	13.32	34.65	—	—	1
Fagonia arabica L.	12	15.16	44.26	—	1	1
Atriplex griffithii Maq. Var. *stocksii* Boiss.	10	15.15	31.32	—	—	1
Cordia gharaf (Forssk.) Ehren. ex Asch.	9	16.51	23.98	—	—	—
Cassia holosericea Fresen.	9	13.23	65.24	—	1	—
Barleria acanthoides Vahl.	9	10.50	23.76	—	—	—
Aerua persica (Burm. f.) Merrill.	9	9.63	33.42	—	—	2
Pulicaria hookeri Jafri	8	11.30	30.50	—	—	2
Lycium depressum Stocks	8	8.06	28.63	—	—	—
Indigofera oblongifolia Forssk.	7	4.88	10.29	—	—	—
Convolvulus glomeratus Choisy	6	11.41	26.60	—	—	1
Cressa cretica L.	5	21.61	84.95	1	1	—
Acacia nilotica (Linn.) Delile ssp. *astringens* (Schumach and Thonn.) Roberty	5	6.76	22.47	—	—	—
Cucumis prophetarum L.	5	5.60	9.75	—	—	—
Heliotropium obhioglossum Boiss.	4	27.19	100.66	1	—	—
Salvadora oleoides Dcne.	4	14.41	44.70	—	—	1
Aeluropus lagopoides (L.) Trin. ex Thw.	4	14.11	50.66	1	2	—
Capparis decidua (Forssk.) Edgew.	4	12.05	19.72	—	—	—
Rhus mysurensis Heyne. ex Wight and Arn.	4	3.34	3.91	—	—	—
Tamarix indica Willd.	3	139.54	254.27	2	—	1
Boerhaavia stellatus (Wight and Arn.) Berhaut in Bill	3	4.15	5.60	—	—	—
Desmostachya bipinnata (L.) Stapf	2	8.35	10.28	—	—	—
Salsola baryosma (R. and S.) Dandy	2	4.78	9.57	—	—	—
Panicum antidotale Retz.	2	4.02	7.09	—	—	—
Pentatropis spiralis (Forssk.) Dcne.	2	3.35	3.96	—	—	—
Glossonema varians (Stocks) Bth.	1	2.87	2.87	—	—	—

TABLE 2. Summary of absolute phytosociological data.

Species	Average cover per acre (sq. ft.)	Maximum cover per acre (sq. ft.)	Average density per acre	Maximum density per acre
Euphorbia caducifolia Haines	6978.71	16673.10	308.40	2279.61
Tamarix indica Willd.	5316.38	6039.48	1117.71	2634.75
Prosopis cineraria (L.) Druce.	1938.92	8136.56	250.78	1519.74
Commiphora wightii (Arnott.) Bhandari	1134.14	5998.83	169.58	506.58
Zizyphus nummularia (Burm. f.) Wight and Arn.	1040.93	1365.36	153.65	606.97
Salsola baryosma (R. and S.) Dandy.	956.89	1788.04	14.76	21.24
Lycium depressum Stocks.	513.61	1485.47	155.48	1013.16
Salvadora oleoides Dene.	483.21	1619.80	42.44	82.48
Heliotropium ophioglossum Boiss.	467.42	1849.71	369.50	1478.02
Capparis decidua (Forssk.) Edgew.	305.07	708.38	47.24	76.65
Aeluropus lagopoides (L.) Trin. ex Thw.	212.67	442.87	712.43	1458.53
Panicum antidotale Retz.	185.78	310.66	82.48	48.42
Cassia holosericea Fresen.	133.05	1051.59	160.15	969.96
Pulicaria hookeri Jafri	118.64	689.62	71.98	253.29
Indigofera oblongifolia Forsk.	108.99	620.19	34.29	58.14
Cordia gharaf (Forssk.) Ehren. ex Asch.	107.01	321.74	58.87	127.96
Aerva persica (Burm. f.) Merrill.	100.07	495.75	64.99	253.29
Grewia tenax (Forssk.) Aschers and Schweinf.	90.36	263.19	85.95	253.34
Cressa cretica L.	79.22	256.55	694.10	3099.39
Acacia nilotica (Linn.) Delile ssp. *astringens* (Schumach and Thonn.) Roberty.	64.67	156.14	11.56	16.75
Fagonia arabica L.	52.93	301.17	210.81	1519.74
Barleria acanthoides Vahl.	39.88	203.64	83.63	253.29
Desmostachya bipinnata (L.) Stapf.	24.53	35.36	185.55	217.80
Boerhaavia stellatus (Wight and Arn.) Berhaut in Bill.	21.87	54.16	12.08	15.33
Convolvulus glomeratus Choisy	17.30	37.51	115.19	561.09
Atriplex griffithii Moq. var. *stocksii* Boiss.	16.92	65.27	104.44	374.06
Cucumis prophetarum L.	14.70	104.44	40.06	43.51
Rhus mysurensis Heyne. ex. Wight and Arn.	3.48	7.29	13.61	18.21
Glossonema varians (Stocks) Bth.	1.71	1.71	6.08	6.08
Pentatropis spiralis (Forssk.) Dcne.	1.19	2.91	11.71	18.21

and *Salvadora oleoides* were not common. It was observed that due to disturbance number of abnoxious plants, that are not the characteristic plants of the region, are favoured, e.g.; *Cassia holoscrecia, Salsola baryosma, Aerva persica, Calotropis procera, Prosopis juliflora* which constitute indicator plants of disturbed condition.

The only tree species, *Prosopis cineraria* is very abundant in the study area. It is also a climatic climax of arid regions of Pakistan. It often grows wherever ample amount of soil has been produced. According to Chaudhri (1952) it is a tree having a very deep root system; the shallow soil cannot provide a suitable substratum to this plant. Among the tall shrubs, *Euphorbia caducifolia* is very conspicuous and gives a characteristic physiognomy to the vegetation since it is a succulent cactoid upsurge and is represented with a high I.V.I. in non-saline soils. The next important shrub is *Commiphora wightii.* It is a very xerophytic plant (it remains deciduous for most part of the year) and in almost all the stands has high I.V.I. Most common climber is *Pentotropis spiralis* which is usually seen twining around the branches of *Euphorbia caducifolia, Commiphora wightii* and *Prosopis cineraria.* Similarly *Convolvulus glomeratus* is very often associated with *Commiphora wightii.*

(b) *The vegetational ordination:*

Fig. 1 shows the three-dimensional vegetational ordination. Most of the compositional variation was accounted for by the X and Y-axes whereas Z-axis contained little useful information. The mechanical validity of the ordinations was checked i.e., it was determined that how well the stand distance in the 3-dimensional space correspond with the values of dis-similarity of the Q-type matrix which showed for a random sample of 50 pairs of values a correlation coefficient of 0.370 which is highly significant ($P \leqslant 0.01$). This remarkable correlation clearly demonstrates the tendency for the ordination to approximate the actual vegetational similarities.

The primary axis of the ordination is largely determined by the proportions of *Euphorbia caducifolia, Prosopis cineraria, Zizyphus nummularia* and *Commiphora wightii;* the secondary axis is chiefly a measure of the proportion of *Prosopis cineraria, Salvadora oleoides, Pulicaria hookeri* and *Commiphora wightii;* whereas tertiary axis is mainly governed by the proportion of *Artiplex griffithii* and *Grewia tenax.*

The behaviour of species along phytosociological gradients:

The behavioural patterns of ten common perennials, as expressed by their importance values, are represented separately on xy—ordination plane in Fig. 2. Since Z-axis contained little ecological information owing to distortion, the behaviour of species along this axis is not presented. *Euphorbia caducifolia* is widely distributed and exhibits I.V.I. in all the stands except a few situated at the right side of X-axis where it has relatively less I.V.I. *Zizyphus nummularia* attains high importance values at low levels of X-axis and almost medium positions of Y-axis. *Prosopis cineraria,* though widely distributed, exhibits higher importance values at the upper left portion of the vegetational ordination likewise, *Commiphora wightii* is also widespread but attains higher I.V.I. at medium position on the Y-axis (with the exception *persica* behave more or less indifferently in relation to the phytosociological ordination.

(c) *Relationships between environmental variables and stand composition:*

Data on edaphic characteristics is presented in Table 3. Among the various physical and chemical measurements of soil only five variables namely soil pH, of one stand) and behaves indifferently in relation to X-axis. *Pulicaria hookeri* shows restricted distribution and attains its higher importance values at medium level of X-axis and high positions on Y-axis. Though *Cressa cretica* is widely distributed but attains prominence at the lower left-hand corner of the ordination. *Atriplex griffithii* is confined to the right-hand portion of the ordination and is completely absent in the left-side. *Convolvulus glomeratus, Grewia tenax* and *Aerua*

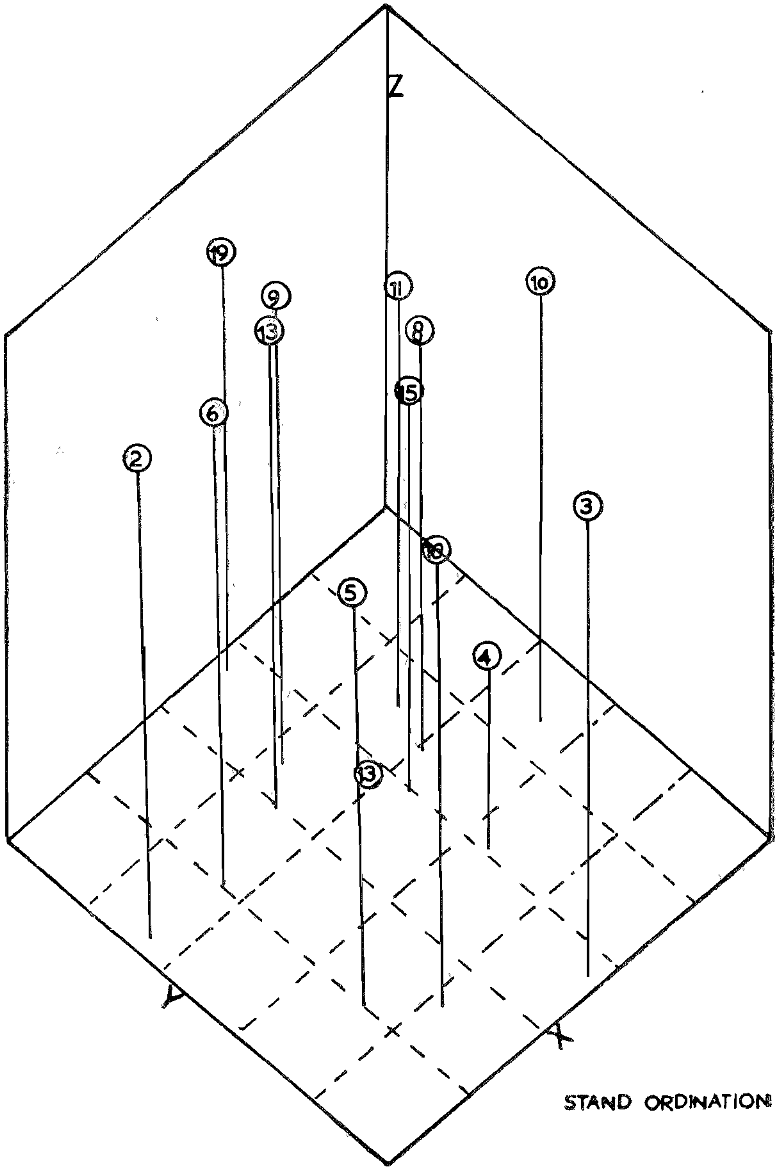

Fig. 1. The three-dimensional vegetational ordination.

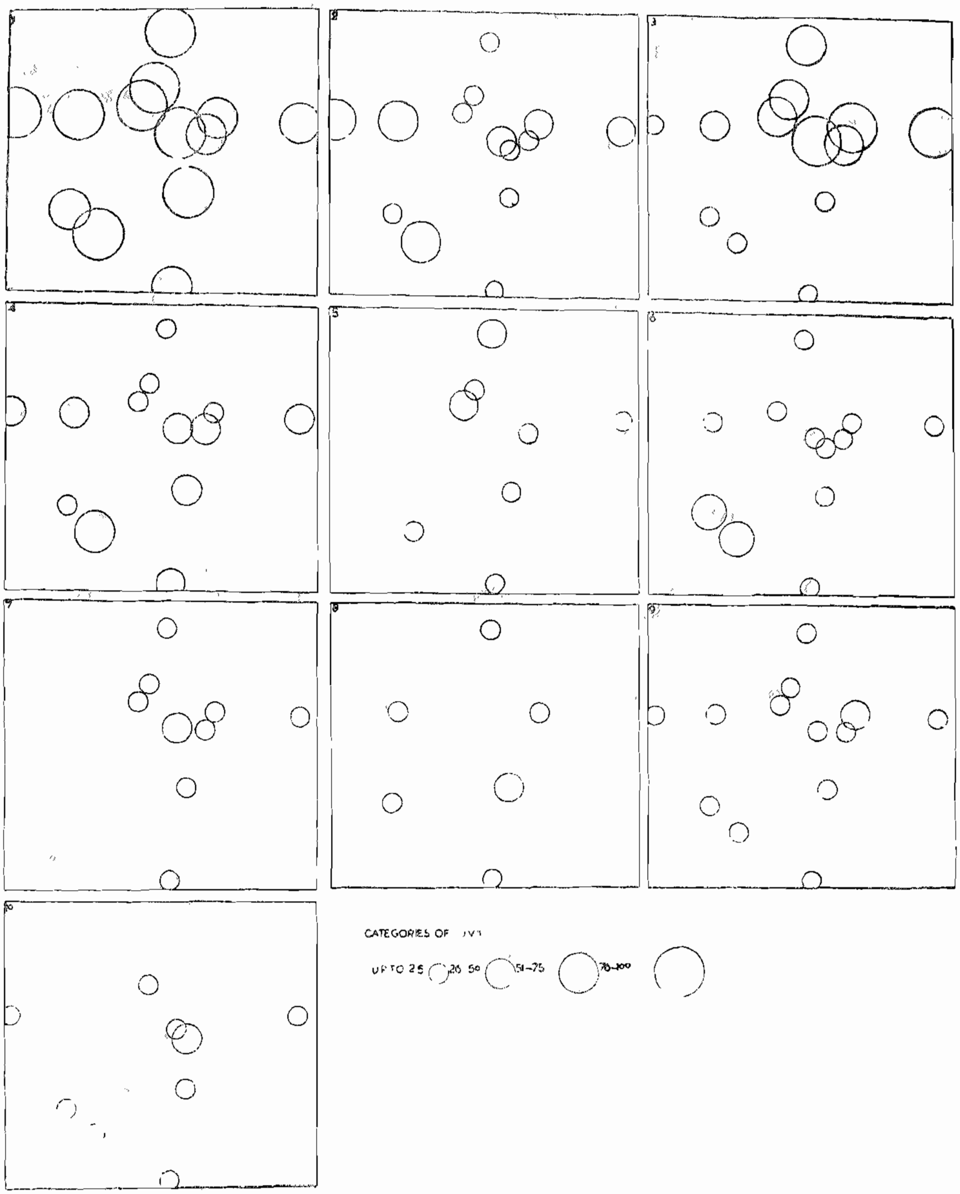

Fig. 2. The behavioural pattern of 10 important perennials in the XY—plane of the vegetational ordination.

1. *Euphorbia caducifolia.*
2. *Zizyphus nummularia.*
3. *Prosopis cineraria.*
4. *Commiphora wightii.*
5. *Pulicaria hookeri.*
6. *Fagonia arabica.*
7. *Atriplex griffithii.*
8. *Convolvulues glomeratus.*
9. *Grewia tenax.*
10. *Aerua persica.*

CaCO$_3$, soil depth, maximum water holding capacity and silt plus clay exhibited consistent relationship with the vegetational composition when the edaphic variables were related to vegetational ordination (Fig. 1). The stands in which *Euphorbia caducifolia* is the leading dominant (stands 2,4, 5,6,9,13,18,19) most of which are clustered together in the vegetational ordination (Fig. 1) have soil pH from 6.8 to 7.2. Stands of water-logged saline soils which are free from disturbance (stand 1 and 20) show high soil pH viz. 8.2 and 8.6 but three other stands which have recently received acidic industrial effluents from the nearby industries showed low pH inspite of halophytic vegetation (with the exception of one stand). Soil calcium carbonate is usually high in stands in which *Prosopis cineraria*, the climatic climax of the area, is the leading dominant (viz. stands 8,10 and 11); such stands are closely located in the vegetational ordination (Fig. 1). Stands in which *Euphorbia caducifolia* is the leading dominant in general occur on soils that have moderate CaCO$_3$ content (15.78 to 20.42% excluding stands 13 and 19 where CaCO$_3$ is relatively low). Stands of water-logged saline soils (not included in vegetational ordination) viz. stands 1,7,17 and 20 generally have low CaCO$_3$ content of soil (Table 3). *Prosopis cineraria* shows high I.V.I. on deep soils whereas *Commiphora wightii* attains prominence on shallow soils. In general stands of water-logged sites were found to be associated with deep soil (Table 3). Other species did not exhibit definite response to changes in soil depth. Stands in which pioneer species like *Pulcaria hookeri*, *Fagonia arabica*, *Convolvulus glomeratus* and *Atriplex griffithii* are prominent (viz. stands 4,5,9,12,13 and 19) are usually associated with soil that have low maximum water holding capacity; among these stands 19, 13 and 12 are closely situated in the vegetational ordination (Fig. 1). In contrast, stands of water logged saline soils are found on soils that possess high maximum water holding capacity (Table 3). The combined percentage of silt and clay exhibits similar relationship with stand composition as the maximum water holding capacity since the latter is directly dependent upon the former.

(d) *Species ordination:*

Fig. 3 shows the ordination of 17 most abundant species. The distances of species (represented by dots) in three dimensions and the corresponding dissimiliarty values of the R-type matrix gave for a random sample of 25 pairs a highly significant correlation ($r=0.631$, $p < 0.001$) indicating that the ordination of specie very elegantly portrays the actual ecological relationships among the species. The ordination used *Convolvulus glomeratus* and *Prosopis cineraria* as reference points for the construction of primary axis. The former is a pioneer species and the latter is the climatic climax of the region; consequently the primary axis represents a successional gradient. *Heliotropium ophioglossum* (a characteristic plant of slightly disturbed vegetation) and *Fagonia arabia* furnished the reference set for secondary axis. Whereas, *Pulicaria hookeri*, a species of shallow calcarious soil and *Capparis decidua*, a plant that occurs on sand dunes, (or on deep soils) provided the end points for the erection of tertiary axis of the species ordination. Though the distribution of species in the ordination is essentially continuous yet a few somewhat discrete clusters of species are readily distinguishable. *Fagonia arabica*, *Lycium depressum* and *Atriplex griffithii* form a group at the upper middle and upper left position of the XY-and YZ-plane respectively, but in the XZ-plane these species, though closely situated, are mingled with other species. *Cordia gharaf*, *Zizyphus nummularia* and *Grewia tenax*, which are characteristic plants of relatively fine textured soil of medium depth, are situated in close vicinity in the ordination at the central portion, middle-left, and more or less middle position in the XY, YZ and XZ ordioation planes respectively. *Pulicaria hookeri* and *Barleria acanthoides*, which can withstand shallow soils, are situated in close proximity in all the three ordination planes.

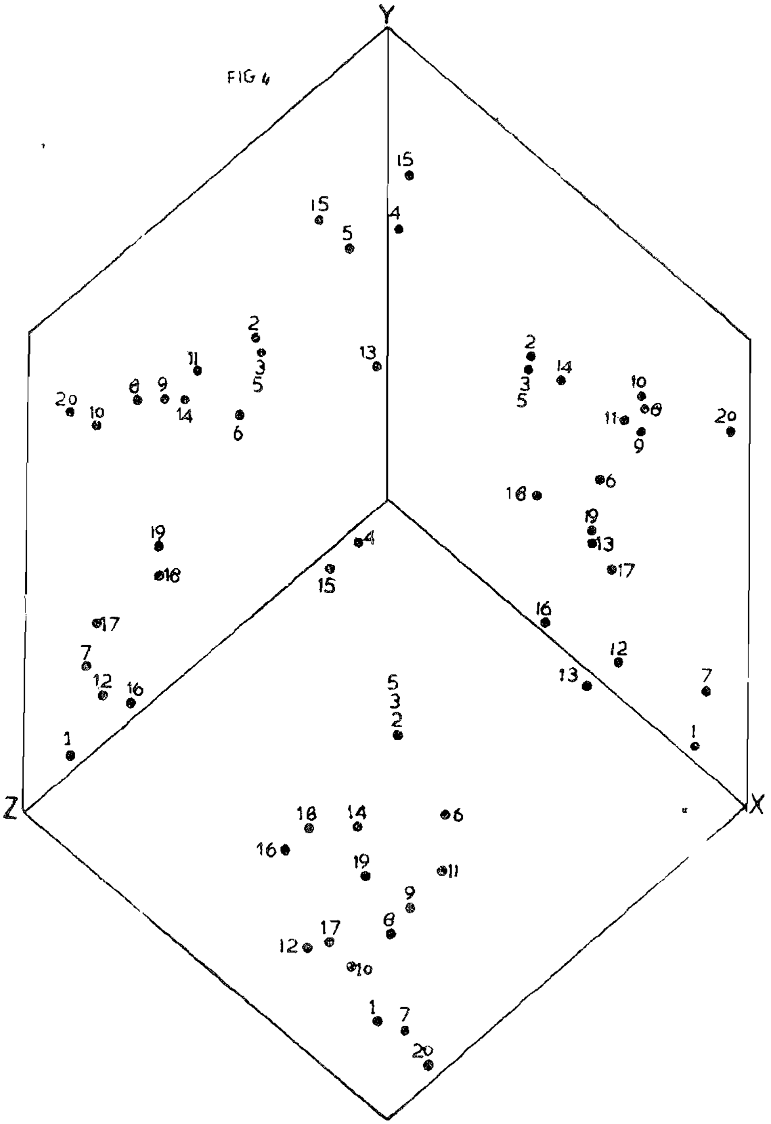

Fig. 3. The three-dimensional species ordination.

Ag,	*Atriplex griffithii.*	AP,	*Aerva persica.*
Ba,	*Barleria acanthoides*	Cd,	*Capparis decidua*
Cg,	*Cordia gharaf.*	Cgl,	*Convolvulus glomeratus.*
Ch,	*Cassia holosericea.*	Cw,	*Commiphora wightii.*
Ec,	*Euphorbia caducifolia.*	Fa,	*Fagonia arabica.*
Gt,	*Grewia tenax.*	Ho,	*Heliotropium ophioglossum.*
Io,	*Indigofera oblongifolia.*	Ld,	*Lycium depressum.*
Pc,	*Prosopis cineraria.*	Ph.	*Pulicaria hookeri.*
Zn,	*Zizyphus nummularia.*		

TABLE 3. Data on edaphic variables of the stands.

Stand No.	pH	Organic matter %	$CaCO_3$%	Exchangable PO_4(ppm)	Soil depth (inches)	Maximum W.H.C.%	Soil texture				Community
							Sand (%)	Silt (%)	Clay (%)	Silt & Clay (%)	
1.	8.2	1.96	8.19	.30	23.5	38.19	53.80	21.98	18.01	39.92	Ti — Al
2.	7.0	0.51	19.26	.15	17.8	26.11	70.47	5.92	10.09	16.10	Ec — Zn — Cw
3.	7.3	1.63	19.26	.15	9.4	27.60	70.47	5.92	10.09	16.01	Cw — Sb — Fa
4.	6.8	1.15	20.42	.15	11.4	27.10	85.72	8.95	3.01	11.96	Ec — Cw — Cg
5.	7.2	.76	18.46	.20	15.5	28.56	79.38	5.52	10.11	15.63	Ea — Fa — Pc
6.	7.2	.83	17.26	.20	8.7	29.63	78.16	7.06	11.52	18.58	Ec — Zn — Pc
7.	6.2	1.13	7.10	.35	24.0	37.10	57.03	23.32	17.42	40.47	Ti — Cc — Al
8.	6.9	1.62	24.55	.10	12.4	29.38	65.29	20.19	15.09	35.28	Pc — Ec — Cw
9.	6.9	.71	19.41	.10	5.11	25.86	70.20	15.68	10.28	25.96	Ec — Pc — Ph
10.	7.8	1.36	29.46	.05	12.3	29.46	60.03	20.13	16.75	36.88	Ec — Cw — Ec
11.	8.00	1.36	28.33	.15	17.4	28.93	71.00	9.08	12.95	22.03	Pc — Ec — Gt
12.	7.1	.90	6.34	.05	17.7	26.94	61.85	20.28	15.11	35.39	Pc — Ec — Ag
13.	7.1	.64	10.11	.03	7.9	25.10	85.68	4.52	5.53	10.05	Ec — Pc — Fa
14.	6.2	1.23	15.24	.40	10.3	32.56	72.65	13.25	10.53	23.78	Sm — Sb — Pj
15.	6.7	1.18	34.17	.20	6.1	25.11	83.00	12.12	1.32	13.44	Ho — Ch — Ap
16.	6.3	1.68	26.64	.40	14.3	32.94	53.80	20.44	15.25	35.69	Cc — Sb — Ap
17.	6.5	1.49	8.90	.20	24.0	26.47	60.30	20.13	16.75	36.88	Ti — Ld — Cd
18.	7.0	1.86	15.78	.15	13.8	29.49	71.37	18.67	10.01	28.68	Ec — Cw — Zn
19.	6.9	1.44	11.11	.20	15.7	28.03	59.35	10.17	16.09	26.26	Ec — Pc — Ph
20.	8.6	1.10	7.87	.40	24.0	36.87	58.85	23.90	17.00	40.90	Ai — Cc — T

(e) *Environmental ordination:*

Fig. 4 shows the ordination of 20 stands with respect to moisture regime gradient (X-axis), calcicolous gradient (Y-axis) and silt-clay gradient (Z-axis). It is apparent that most of the stands are dispersed to the middle to right portion of the

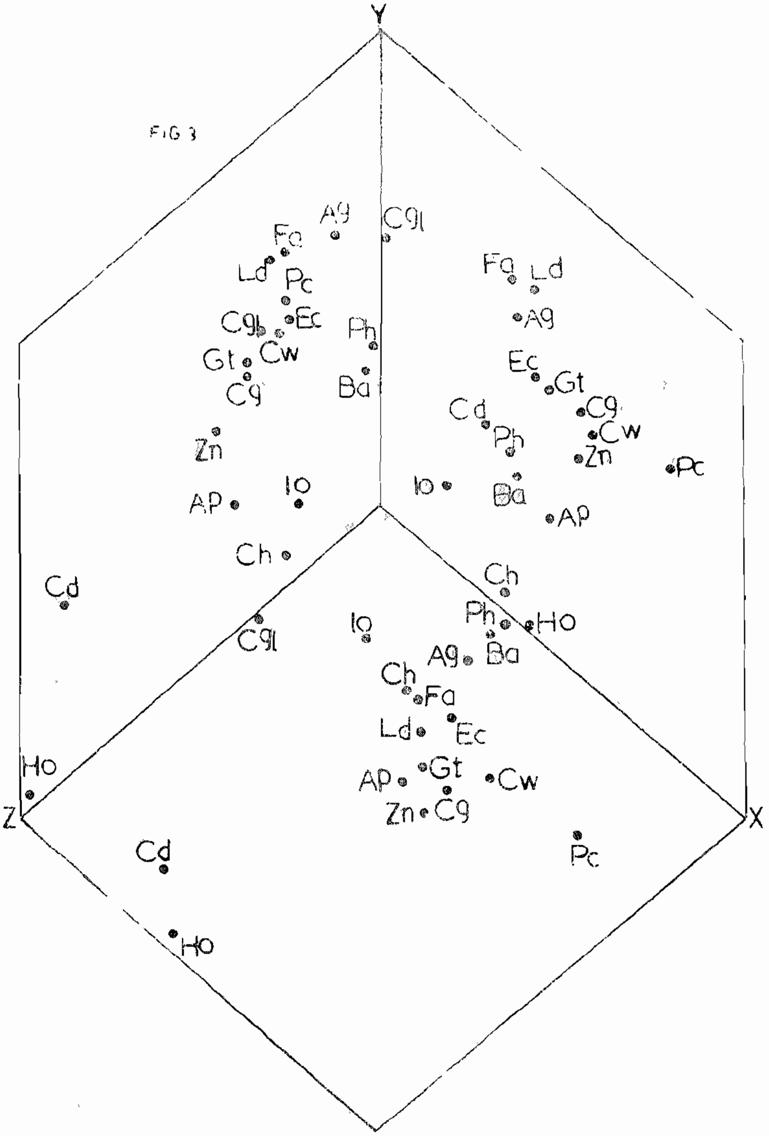

Fig. 4. The three-dimensional environmental ordination.

X, Moisture regime gradient. Y, Calcicolous gradient.

Z, Silt-clay gradient.

X-axis indicating that moderate moisture conditions prevail in such stands. It is noteworthy that stands 8,9,10 and 11 in which *Prosopis cineraria* is dominant and consequently represent climax vegetation occupy high position on the moisture regime gradient. In the XY-plane majority of stands fall in the upper half of the plane which shows that most species constituting the vegetation are very calcicolous in nature. In general, stands in which *Euphorbia caducifolia* shares dominance with *Commiphora wightii*, *Grewia tenax* and *Fagonia arabica* (all of which are regarded as extremely calcicolous species) e.g. stands 2,3,2,4,5,6 and 11 are located at medium to high positions on the calcicolous gradient, in contrast to this, stands of water-logged and saline conditions have low positions on the Y-axis, indicating that calcarious soil conditions are unfavourable to the growth and abundance of the constituent species of such stands. On the silt-clay gradient (Z-axis), stands which have attained climatic climax or physiographic climax tend to occupy high positions, whereas stands that are in intermediate stages of succession generally have low positions. Though there are a few discrepencies from the afore-mentioned generalizations but these are ascribable to certain kinds of mild disturbances e.g. grazing, cutting and trampling.

(f) *The behaviour of species along environmental gradients:*

The distributional patterns of the 10 important perennials is displayed in Fig. 5 using four categories of I.V.I. with the aid of various circle-sizes, in XY-XZ and YZ-ordination planes, separately for each species. *Grewia tenax* is distributed (with low I.V.I.) at the medium position on moisture and calcicolous gradients but is indifferent to silt-clay gradient. Likewise *Fagonia arabica* attains prominence at more or less middle part of the moisture and calcicolous gradients and at low positions on the silt-clay gradient. *Tamarix indica* exhibits higher I.V.I. at high level of moisture status and silt-clay gradient and low level of calcicolous condition. *Commiphora wightii* also attains high inportance values at somewhat middle position on moisture regime gradient and middle to high positions on the calcicolous gradient. The behavioral pattern of *Zizyphus nummularia* is similar to that of *Commiphora wightii*. *Heliotropium ophioglossum* shows high I.V.I. at low position on moisture and silt-clay gradient and at high level of calcicolous gradient. *Cressa cretica* attains high importance values at high positions on moisture and silt-clay gradients but is indifferent to calcicolous gradient. *Prosopis cineraria* exhibits prominence at high positions on moisture regime and silt-clay gradients but behaves irregularly with respect to calcicolous gradient. *Euphoribia caducifolia*, though widely distributed with mostly high I.V.I., attains conspicuousness at somewhat medium positions on moisture regime gradient but is indifferent to either gradients. *Atriplex griffithii* is mostly distributed at medium levels of moisture regime gradient, though with low I.V.I., and behaves irregularly on the other two gradients of the environmental ordination.

Discussion and Conclusions

The vegetation in the surveyed area exhibits local compositional variation in response to diverse physiographic conditions. Two distinct physiographic situations were encountered—namely sandy plains and water-logged saline sites. These differ considerably in micro-relief, soil-depth and certain edaphic characteristics related to moisture availability and nutrient supply, and consequently represent distinct habitats. The vegetation of sandy plains is principally constituted by perennial xerophytic shrubs like *Euphorbia caducifolia*, *Prosopis cineraria* *Commiphora wightii*, *Zizyphus nummularia*, *Fagonia arabica*, *Grewia tenax* *Atriplex griffithii* and *Heliotropium ophioglossum*. In contrast, the vegetation of water-logged saline sands is chiefly composed of halophytes like *Tamarix indica*, *Aleuropus lagopoides*, *Cressa cretica*, *Salvadora persica* and *Desmostachya bipinnata*.

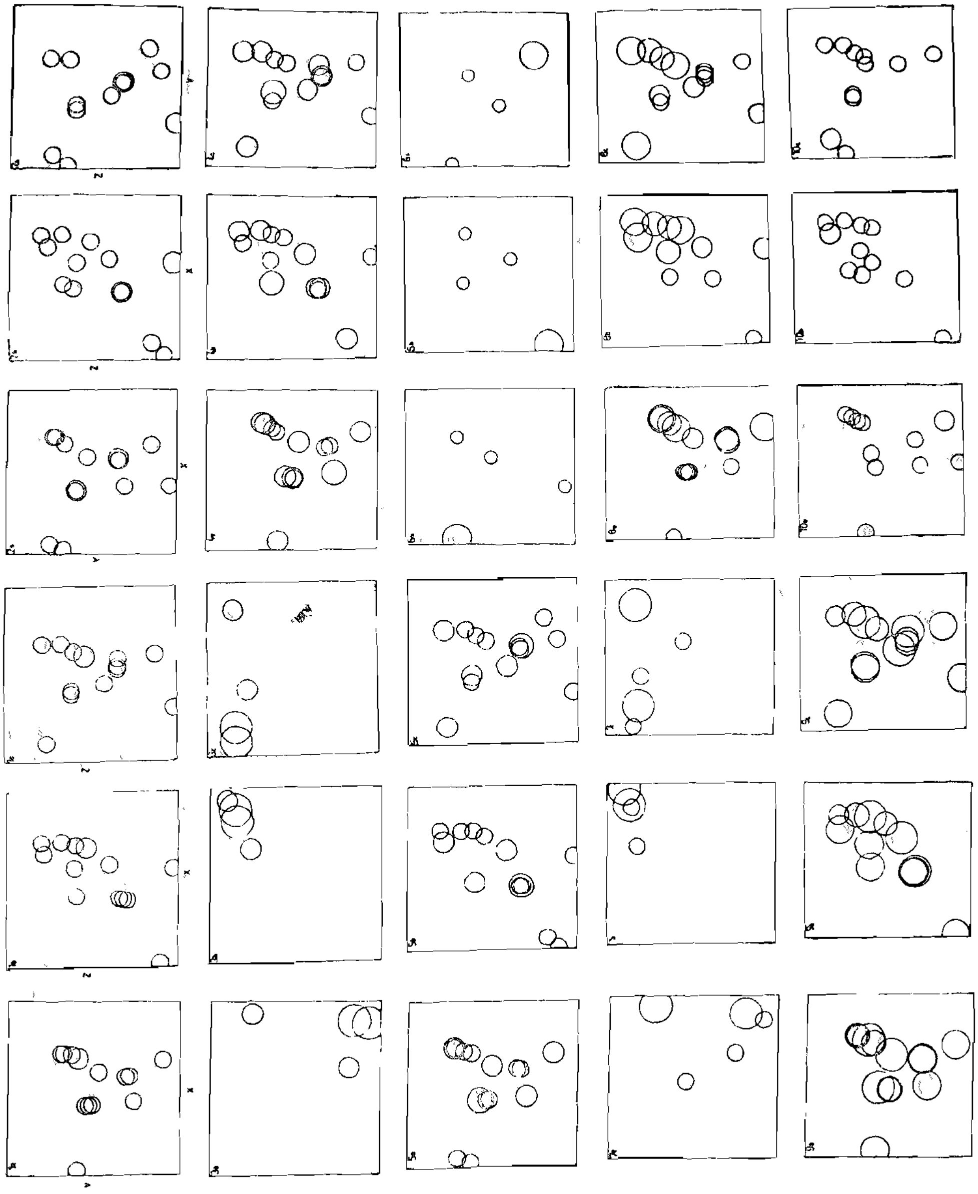

Fig. 5. Distribution pattern of 10 important perennials in relation to environmental gradients.

1. *Commiphora wightii.*
2. *Fagonia arabica.*
3. *Tamarix indica.*
4. *Euphorbia caducifolia.*
5. *Zizyphus nummularia.*
6. *Heliotropium ophioglossum.*
7. *Cressa cretica.*
8. *Prosopis cineraria.*
9. *Grewia tenax.*
10. *Atriplex griffithii.*

The sub numbars a,b,c refer to xy, xz and yz ordination planes.

Despite limitations in sampling technique the vegetational ordination successfully elucidated the pattern of vegetational composition. The spatial configuration of stands in the three-dimensional vegetational ordination provided evidence that most of the variation in vegetational composition is expressed by the primary and secondary axis. This suggests that the distribution pattern of vegetation in the study area is predominately governed by two groups of related environmental factors. This prediction of vegetational ordination was confirmed by the environmental ordination. Examination of behavioral pattern of species in the frame-work of environmental ordination disclosed that the compositional variation is largely controlled by the moisture regime and calcicolous gradients.

The fashion in which stands scattered in both the vegetational and environmental ordinations suggests that discrete communities do not exist and had stands been arranged in a linear continuum (e.g. Brown & Curtis, 1952; Christensen *et al*, 1959) many of the important relationships would not have been apparent. The study of distribution pattern of species in the vegetational and environmental ordinations indicates that each species has its own characteristic pattern, different in spatial area, location and the position of conspicuousness (in ordination) from others and no two species are distributed alike. This confirms the individualistic hypothesis which has variously been attributed to Gleason (1917, 1926) and certain other ecologists cf. Aleksandrova, 1973; Whittaker, 1973; Sobolev & Utekhin, 1973) and which comprises the crux of modern ecological theory and community analysis (McIntosh, 1975). With a few exceptions, each species showed an atmospheric or part of an atmospheric distribution and indicated a separate area of location. Moreover, the distribution of each species is interspersed to varying degree with other species resulting in a continuous change in composition from one part of the ordination to any other part. Thus the continuum patten of vegetation as described by the workers of Wisconsin School (e.g. Curtis, 1959; Beals, 1965; Goff & Zedler, 1968) is readily perceptible, and although it is predominately attributable to moisture regime and calcicolous gradients, is also in part due to mild disturbance owing to occasional grazing, cutting of bushes and trampling. The continuum pattern of vegetation does not, however, preclude the possibility of the establishment of arbitrary community types (Becking, 1968; Whittaker, 1975). Nor are rapid or discrete changes in edaphic conditions, such as between sandy plains and water-logged saline sites inconsistent with the continuum concept (McIntosh, 1967). Daubenmire (1966), refuting the continuum concept, asserts that continuous variation in the distribution of vegetation occur only in disturbed areas whereas well-defined, discrete entities may be distinguished where vegetation is in pristine condition. Future ecological studies will have to be conducted in more or less disturbed areas, since pristine areas are diminishing owing to increasing population pressure, urbanization and exploitation of land. Thus, Wikum & Wali (1974) suggest that the patterns of vegetation must be recognized as they exist.

It has been concluded by Whittaker & Gauch (1973) and Shaukat (1976) that greater understanding of the vegetational-environmental data may be attained when direct and indirect ordination techniques are employed in conjunction with each other. To fulfill the objectives of the present investigation; therefore, three different ordination approaches—namely vegetational environmental and species ordinations were employed. Each of them, though serving a unique purpose, is complementary to the others in gaining an insight of the underlying pattern in the vegetational-environmental samples.

The vegetational ordination (indirect gradient analysis) approach of the Wisconsin school (Bray & Curtis, 1957; Loucks, 1962; Beals, 1965; Shaukat & Qadir 1971) has certain advantages over the environmntal ordination (direct gradient analysis). If environmental data do not lend themselves to direct gradient analysis, in case environmental gradients are not readily apprehended or if additional gradients are contemplated beyond those used for environmental ordination, the vegetational ordination then enables one more clearly to discern patterns of compositional variation. A vegetational ordination was, therefore, constructed to overcome such difficulties. The vegetational ordination not only defined the pattern of vegetational composition but also provided evidence on the influence of the prevailing environmental gradients when the species responses to environmenal variables were examined with reference to their dominance behaviour in the vegetational ordination. Although, the apparent objectivity of vegetational ordiations is one of their central features, the results from these techniques are sometimes not readily interpretable. In a number of cases distortions have been noticed, particularly of higher axes (McIntosh, 1972; Gauch & Whittaker 1973; Whittaker & Gauch, 1972; Pemadasa *et al*, 1974). In the present vegetational ordination the tertiary axis did not yield interpretable information, presumably owing to nonmonotonic nature of species distributions (Swan, 1970; Westman, 1971; Gauch & Whittaker, 1972). Furthermore, indirect gradient analyses are found to be disruptively sensitive to beta diversity (change per unit compositional gradient), thereby alleviating the predictability of the ordination (Gauch & Whittaker, 1972; Whittaker & Gauch, 1973; Bratton, 1975). Orloci (1974) demonstrated that distortion in the vegetational ordination may also occur when the distance function is incompatible with the ordination geometry. However, the semimetric distance measure employed in the present study automatically incorporates the double standardization, when relative data is used (cf. Austin & Greig-Smith, 1968; Austin & Noy-Meir, 1972; Poole, 1974), and has been shown to yield better results, in comparison to metric resemblance function. when employed in conjunction with the multi-dimensional scaling technique of polar ordination (Bannister, 1968; Whittaker & Gauch 1973).

Although the compositional gradients are reflected on the vegetational ordination, the interrelationships among the different species encountered in the survey can more profitably be appreciated from species ordinations. It is apparent from the species ordination that *Fagonia arabica*, *Lycium depressum* and *Atriplex griffithii* are more closely ecologically related to each other than to other species, since they invariably occur as pioneer species in the successional sequence on sandy plains. Ecological propinquity is also depicted among *Cordia gharaf*, *Zizyphus nummularia* and *Grewia tenax*, which are characteristic plants of relatively fine textured soil of medium depth. *Pulicaria hookeri* and *Barleria acanthoides* which can withstand shallow or rocky soil occur together in various planes of the species ordination. Thus the proximity of species positions in the ordination are solely governed by their ecologieal affinity and systematic relationship of the taxa have no bearing on the propinquity of species in the ordination planes.

The study of the relationship of environmntal variables with the stand composition disclosed that five edaphic characteristics, namely pH, $CaCO_3$, soil-depth, maximum water holding capacity and combined percentage of silt and clay have an over-riding influence over other variables in controlling the distribution behaviour of the major species.

The environment, however, acts upon the plant community as a whole rather than in the form of units; consequently the components of the environment considered separately do not represent the holocoenotic nature of the environment (Cain, 1944). In addition, problems of factor selection, interaction, duration and limiting factors (Billings, 1952; Daubenmire, 1959) impose great limitations on the interpretation of relationships between environmental variables and vegetational composition. Billings (1952) suggested that the analysis of individual factors in relation to vegetation should be followed by a comprehensive synthesis of groups of related variables that are known to have a significant bearing on vegetational composition into factor complexes. The response of various species to such factor complexes should then be assessed. The paracticability and significance of such a synthesis has been demonstrated by Loucks (1962), Monk (1965, 1966) and Lewin (1974). Synthetic environmental models allow multidimensional interpretation leading to results, otherwise lost in single factor analysis.

The related edaphic characteristics that exhibited distinct relationship with the vegetational composition were employed in the construction of the environmental ordination. The soil pH and the percentage of calcium carbonate upon which the former greatly depends, together determine the abundance of calcicolous plants of of varied degree. These two edaphic factors have been shown to have a considerable bearing on the pattern of compositional variation in arid or semi-arid regions (Qadir *et al* 1966, Ayyad & Ammar, 1974, Shaukat *et al*, 1976) and were also found to be markedly correlated with the vegetational composition in the present study. Thus, soil pH and percentage of $CaCO_3$ were integrated to yield the calcicolous gradient. The depth of soils and maximum water-holding capacity, which are appreciably correlated with the vegetation type, represent the moisture status of the stands. Within soils of a given texture, the depth of soil is of considerable significance, particularly in case of shallow soils (Wilde 1958). The greater the depth of soil, greater is the hydric reserve. Whereas, maximum water-holding capacity (MWHC) of soil is a hydro-physical property that not only expresses moisture retaining property of soil that determines the continuity of water supply but is also indicative of the availability of moisture to the vegetation. Consequently, soil depth and MWHC were integrated to produce the moisture regime gradient. The combined percentage of silt and clay, that represents the soil fertility (cf. Loucks, 1962) furnished the silt-clay gradient as the tertiary axis of the environmental ordination.

The use of ordination techniques discloses the distributional relationships among species. When environmental data are employed as the basis of determining habitat similarity one can clearly define the environmental mosaic and the conditions which favour a given species to attain its maximum importance. However, the environmental ordination is not a literal representation of the environment *in toto* but an approximation of a three principal dimensions of the environment. If more environmental factors are employed (to which the species are responding) a more complete picture of the ecosystem would be forthcoming.

The study leads to the conclusion that a better understanding of the ecology of an area can only be achieved by making use of vegetational, environmental and species ordinations in conjunction with each other.

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