DOI: http://dx.doi.org/10.4314/star.v4i2.17
ISSN: 2226-7522(Print) and 2305-3372 (Online)
Science, Technology and Arts Research Journal
Sci. Technol. Arts Res. J., April-June 2015, 4(2): 139-148
Journal Homepage: http://www.starjournal.org/

Original Research

Multivariate Analysis of Some Mangrove Forests from Coastal Areas of Pakistan

Kanwal Nazim[1], Moinuddin Ahmed[2], Syed Shahid Shaukat[2], Muhammad Uzair Khan[1], Nasrullah Khan[3]* and Agha Tahir Hussain Durrani[4]

[1]Marine Reference Collection and Resource Centre, University of Karachi, Pakistan

[2]Laboratory of Dendrochronology and Plant Ecology, Department of Botany, Federal Urdu University of Arts, Science and Technology Karachi, Pakistan

[3]Laboratory of Plant Ecology, Department of Botany, University Malakand, Chakdara Lower Dir Khyber, Paktunkhawa, Pakistan

[4]Sindh Forest Department, Karachi, Pakistan

Abstract

This study focused on the multivariate analysis i.e. cluster analysis and ordination of twenty eight stands of mangrove forests at six different sites i.e. Sandspit, Port Qasim, Kemari, Korangi Crossing, Ketti Bunder and Sonmiani. For quantitative measurement 10 x10 square feet quadrats were made randomly at 25 m intervals and small quadrats (1 X 1 m^2) were laid inside the main quadrats for quantitative sampling of pneumatophores. The relationships between vegetation and physico-chemical properties were also investigated. The group structure was exposed by an agglomerative clustering technique while major trends were disclosed by PCA ordination. The results of the cluster analysis showed that the six groups of tree vegetation were associated with density/ha and to more or lesser extent with physico-chemical variables. Some of the edaphic variables such as soil nutrient showed significant or weak linear relationships with one or more ordination axes.

Article Information

Article History:
Received : 12-04-2015
Revised : 19-06-2015
Accepted : 22-06-2015

Keywords:
Mangrove forests
Coastal areas
Classification ordination
Conservation and management

***Corresponding Author:**
Nasrullah Khan
E-mail:
nasrullah.uom@gmail.com

INTRODUCTION

Mangrove forests are the tropical coastal ecosystems which are extremely important ecologically and economically as they protect coastal lines, harbors and support coastal fisheries and provide natural nurseries for animals. The root system also provides habitat for invertebrates, such as sponges, crabs, molluscs and oysters as well as many adolescent fish species. Mangroves are dominated by several species of trees or shrubs that grow in salt water. These trees have shallow, widely spread roots that extend from their trunks and branches to anchor them to the bottom. Some species bear pneumatophores that stick out from the mud surface for facing anaerobic situation above the anoxic mud.

Their extensive root system traps and filters plant matter hence they are considered as bio-chemical depositors. The mangrove detritus provides the base of the food chain and commercial forest products (Kathiresan and Bingham, 2001). This primary production forms a significant part of food webs. They have important structural properties including the trapping and stabilization of intertidal sediments; the formation of organic soils; providing protection from wave and wind erosion; provide a vegetative reef surface in the sub-tidal and intertidal zones; and forming a structural complex of a multi-branched forest with a wide variety of surface habitats (Savage, 1972). Mangrove ecosystem is varied with the nature of prevailing environment. These swamps grow only where coastal physiography and energy conditions are favorable.

Pakistan is located between 20°, 50° and 24°, 50° latitude north and 67.50° and 68.15° longitude east. It lies at the junction of three major regions of the sub-continents Asia; Central Asia to the North, the Middle East to the West and the Indian sub-continent to the East. The coastline of Pakistan extends from 990 km to 1050 km long and 490-500 km wide which shares 350 km with Sindh and remaining with Balochistan. The Mangrove forests in Pakistan are distributed at the length of the coast of Sindh and Baluchistan. These forests form a unique part of ecosystem on the deltaic region of the Indus. In Pakistan these forests take fundamental significance because these are found near the harbor in different channels and creeks to protect the land from soil erosion and the effects of storms. These are responsible in cleaning the harbors and cause low maintenance costs of the port. They also act as a pollution controller, naturally filtering out the industrial and human waste. Mangrove swamps, like other wetlands, are important components of the water cycle, absorbing excess water flow during times of flooding. However, in Pakistan mangrove forests have traditionally been used as a source of building poles, fodder and firewood. No considerable work has been done on the management and maintenance of these forests. In order to achieve sustainable forest management there is a need to evaluate the trends in forest conditions over time.

The analysis of multivariate data in ecology is becoming increasingly important (Anderson 2001). Ecologists often need to test hypotheses concerning the effects of experimental factors on whole assemblages of species at once. This is important for core ecological research and in studies of biodiversity or environmental impacts in many habitats, including marine subtidal environments (Warwick *et al.,* 1988; Gray *et al.,* 1990; Chapman *et al.,* 1995; Glasby, 1997), mangroves (Skilleter, 1996; Kelaher *et al.,* 1998), freshwater systems (Faith *et al.,* 1995; Quinn *et al.,* 1996) and terrestrial systems (Oliver & Beattie, 1996). The major objectives of this study are 1) to carry out the structural studies in mangrove forests 2) to present the population studies using multivariate techniques for understanding the community structure, current status and future trend 3) to know the soil-water relationship with mangrove species.

MATERIALS AND METHODS

Quadrat method (Mueller-Dombois and Ellenberg, 1974) was applied for quantitative sampling. Six sites Sandspit, Port Qasim, Kemari, Korangi, Ketti Bunder and Sonmiani were studied. Twenty eight stands were sampled in a random manner having ten replicates of 10x10 m^2 quadrats. The interval was taken from the shore-line to the last mangrove stand following Mendoza and Danilo (2001). All the trees within quadrat with dbh more than 2cm for *A. marina*, *R. mucronata* and *C. tagal* were counted and measured for tree height, basal area and density. A 1x1 meter^2 quadrat were laid inside the main plot for estimating the number and height of pneumatophores. Two hundred leaves were collected from each stand to measure the leaf area from each stand. GPS was used to record position of the stands. The sampling data of same sites were grouped to obtain six different data sets representing six localities surveyed. Due to monospecific nature of most of the stands, the absolute values (density and basal area) were calculated.

Physico-chemical Analysis

The soil and water samples were collected from every stands. All the samples were labeled and brought into laboratory for analysis. Sediments were washed and were oven dried to constant weights. The dried samples were then milled into a fine powder using a mortar and pestle. One gram of dried soil sample was taken in a beaker and digested in 25ml of aqua regia (Berrow and Stein,1983), was heated at 70ºC to dryness add 1ml nitric acid to avoid microbial activity. They were filtered by Whatman No.42 filter paper. Make up 100ml and finally stored for heavy metal analysis. Water samples were then filtered with what man filter paper no.1. Five heavy metals i.e. Fe, Cr, Co, Mn, and Zn were determined by Atomic Absorption Spectrophotometer (Model PG 990).

The organic matter was determined following Ismail, (2002) and the maximum water holding capacity of sediment was determined according to Keen (1931). 25g soil was weighed and a paste was made with distilled water. The paste was filtered with the help of Whatman filter paper No. 42. The filtrate of the sediments and water samples were taken in a small beaker. The other physical parameters salinity, pH, total dissolved solids, conductivity and temperature were measured by Sension multiparameter meter (Model Sension Tm^{105}).

Multivariate Analysis

The clustering strategy was employed namely the agglomerative clustering technique developed by Ward, (1963) and ordination technique Principal Component Analysis (PCA) were employed on data using tree density/ha, basal area m^2/ha, tree height, number of pneumatophores, height of pneumatophores and leaf area. The mean values of all parameters were estimated based on the cluster dendrogram. All the physico-chemical variables were correlated with ordination axes 1, 2 and 3.

RESULTS

The dendrogram resulting from one way cluster analysis for tree data using Ward's method is shown in Figure 1. The dendrogram discloses six main groups at a squared Euclidean distance of 7.1x 10^6 with respect to the density/ha. The species composition in the study area was dominated by broad leaved species *A. marina* of the family Avicenniaceae. The mean values of all parameters in different groups were placed in Table 1.

Table 1: Average value (Mean± SE) of the phytosociological and absolute values of all the groups (commuties types) based on the cluster dendrogram

Groups	Species	Absolute values		H.T (m)	N.P	H.P. (cm)	L.A (cm^2)
		Den/ha	BA(m^2/ha)				
Group 1	*A. marina*	4058±89	7.69±2.06	4.10±0.24	23±2	29.25±6.24	28.57±1.59
Group 2	*A. marina*	3354±62	5.84±0.98	3.54±0.16	23±2.20	26.37±2.95	22.33±2.11
Group 3	*A. marina*	1298.48±83	3.78±0	3.74±0	16±0	24.6±0	11.66±0
	R. mucronata	6059.56±129	4.99±0	3.50±0	-	-	-
Group 4	*A. marina*	2272±62	5.84±0.98	4.15±0.19	38±4	24.97±3.05	25.03±1.66
Group 5	*A. marina*	2759±68	7.72±2.56	3.69±0.24	26±2	22.26±1.61	25.56±1.21
Group 6	*A. marina*	1407±108	7.24±3.78	4.70±0.37	21±11	29.14±4.03	18.84±9.54
	R. mucronata	1731.3	1.97±0	2.37±0.20	-	-	-
	C. tagal	865.65	3.14±0	1.32±0.11	-	-	-

Note: BA=Basal area, H.T. = height of tree, N.P. =number of pneumatophores, H.P= height of pneumatophores, L.A. = leaf area, - = not found

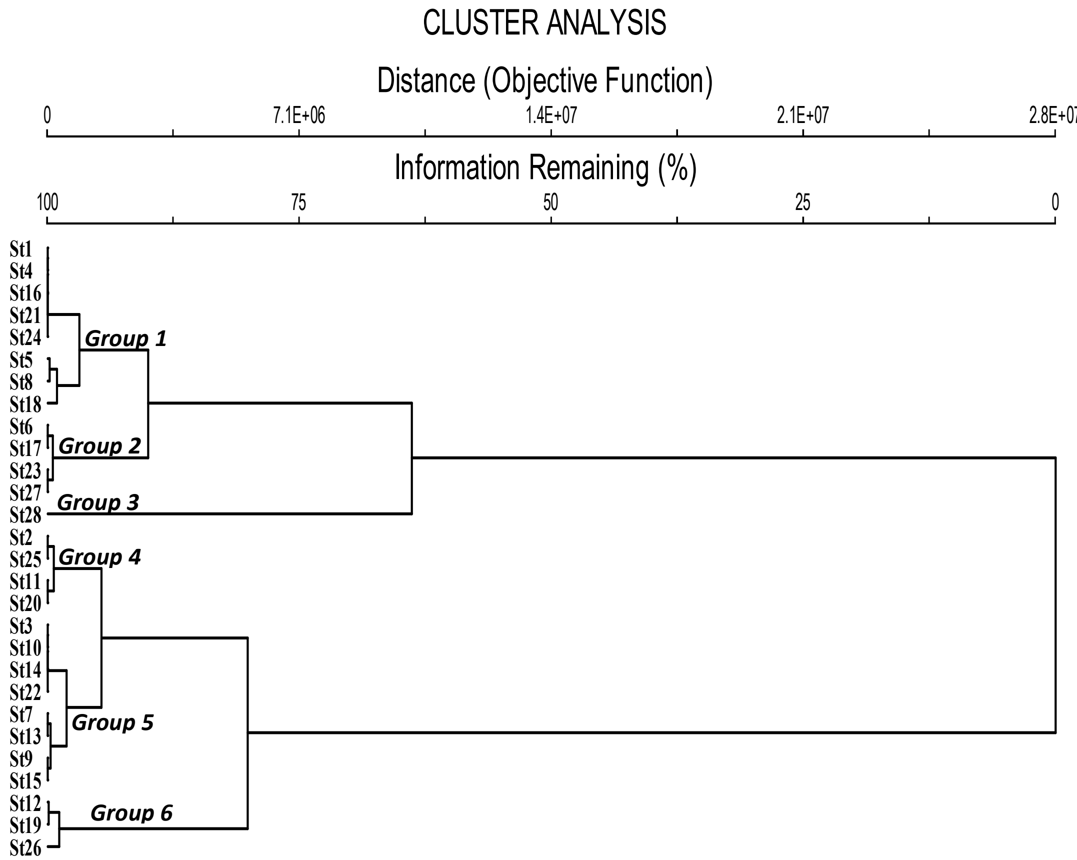

Figure 1: Cluster analysis for 28 Mangrove forest stand using Ward's Euclidean distance method

Group 1

Group1 includes eight stands and was mainly characterized by highest density/ha, basal area m^2/ha, height of pneumatophores and the leaf area of the *Avicennia marina.* The density of this group ranged between 3895 to 4545 with the mean density 4058±89 trees ha^{-1}. This group exhibited the mean value of basal area 7.69±2.06 m^2/ha and height of the trees 4.10±0.24 m respectively. This group occupied the mean number of pneumatophores 23±2 with the maximum height of pneumatophores 29.25±6.24 cm and leaf area 28.57±1.59 cm^2. The results of the physico-chemical parameters revealed.

Group 2

This group was ranked second that includes four stands, showing mean density of 3354±62 trees/ha. The result discloses that density ranged between 3246 to 3463 trees/ha. The basal area of this group varied between 39.42 to 77.94 m^2/ha with an average value of 5.84±9.84 m^2/ha. The tree height of this group ranged 3.32m to 4m with a mean value of 3.54±0.16m. This group occupied the same number of pneumatophores 23±2.2 as group 1. The height of pneumatophores and the leaf area were found 26.37±2.95 cm and 22.33±2.11 cm^2 respectively.

Group 3

This group was designated the smallest group and consists of a single stand. This group was dominated by *Rhizophora mucronata* 6060 trees/ha with the co-dominant species *A. marina* 1296 trees/ha. In this group *R.mucronata* encompassed higher basal area (4.99±0 m^2/ha) followed by *A.marina* (37.84±0 m^2/ha). Least number of pneumatophores (16±0) and leaf area (11.66±0 cm^2) were recorded in this group. The height of the pneumatophores was 24.6±0 cm in this group.

Group 4

This group also includes four stands with the density ranged between 2164 to 2381 trees/ha with an average value of 22721±62 individuals/ha. Similar value of basal area (5.84±0.98 m^2/ha) was recorded from this stand as recorded in group 2. The mean value of tree height was 4.15±0.19m it varied between 3.65 to 4.5m. The maximum number of pneumatophores (38±4m^2) with the greatest height (24.97±3.05 cm) was originated from this group. The mean value of the leaf area was found 25.03±1.66 cm^2.

Group 5

The dendrogram exposed that group as a large group comprised eight stands which acquired third rank due to its density (2759±68 trees/ha). The value of basal area was higher (7.72±2.56 m^2/ha) in this group and the height varied between 2.93 to 4.96m with the mean value of 3.69±0.24m. The number/ height of pneumatophores and leaf area were 26±2, 22.26±1.61 cm and 25.56±1.21 cm^2 respectively.

Group 6

This group contains three stands, in which one stand was associated with *R. mucronata* and *C. tagal* while two stands were occupied by *A.marina*. In this group *R. mucronata* exposed 1731±0 individuals/ha while the average density of *A. marina and C. tagal* were 1407±108 and 866±0 trees/ha respectively. The mean value of basal area for *A. marina* was 7.24±3.78 m^2/ha followed by *R. mucronata* 1.97±0 m^2/ha and *C. tagal* 3.14±0 m^2/ha. This group resided the greatest height (4.7±0.37 m) of *A. marina* while *R. mucronata and C. tagal* dwelled 2.37±0.20 m and 1.32±0.11 m respectively. Number of pneumatophores were 21±1.1, height of pneumatophores was 29.14±4.03 cm and the leaf area was 18.84±9.54 cm^2 respectively.

Physico-chemical Characteristics of Groups

With respect to physico-chemical variables of soil, group 1 showed higher salinity (41.50±2.17 ppt), iron (299.86±17.54 ppm) and cobalt (23.62±1.23 ppm) while Group 2 characterized with low values of sodium (1925.3±0 ppm), potassium (2349.99±0 ppm), magnesium (53.55±6.64 ppm), calcium (2070±90.90 ppm), zinc (18.46±7.82) and chromium (2.61±0.82 ppm). On the other hand, group 3 showed relatively high pH (8.1±0) and maximum concentration of magnesium (78.72.±0 with low values of salinity 22±0 ppt), conductivity (44±0), total dissolved solids (22.3±0), Sulphate (6.47±0ppm), nitrate (185±0ppm), iron (1187.1ppm) and cobalt (19.52±0ppm). However, Group 4 shows least values of pH (6.83±0.47) and Pottassium (2019.72±226.55 ppm) whereas high amount of conductivity (60.59±2.84), total dissolved solids (33.08±1.15 ppm) and calcium (2541.46±39.98 ppm) was recorded from this group. Maximum organic matter (15.10±2.90 %), water holding capacity (54.20±1.66%), Sulphate (7.63±0.29ppm) and nitrate (279.63±25.46 ppm) were found in Group 5 conversely lower organic matter (9.09±2.17%) and water holding capacity (47.47±6.29) were recorded from group 6 with maximum values of sodium (1946.97±97.06 ppm), zinc (39.22±12.34 ppm) and chromium (4.12±1.58 ppm) (Table 2).

Table 2: Mean values of physico-chemical properties of mangrove sediments in groups

Parameters	OC	MWHC	pH	salinity	Conductivity	TDS	Sulphate	Nitrate
Group 1	10.50± 1.73	52.28±4.65	7.51±0.24	41.50±2.17	60.59±2.84	30.86±1.31	7.58±0.36	252.57±21.71
Group 2	14.14±2.74	50.87±2.52	8.0±0.50	37.63±1.60	52.75±4.55	27.13±2.34	7.19±0.56	222.75±33.33
Group 3	11.83±0	51.35±0	8.1±0	22±0	44±0	22.3±0	6.47±0	185±0
Group 4	13±4.79	49.88±4.27	6.83±0.47	41.25±1.65	64.85±2.55	33.08±1.15	6.75±0.51	227±29.23
Group 5	15.10±2.90	54.20±1.66	7.38±0.30	39.89±1.11	57.63±1.85	29.45±0.93	7.63±0.29	279.63±25.46
Parameters	**Na**	**K**	**Ca**	**Mg**	**Zn**	**Fe**	**Co**	**Cr**
Group 1	1878.30±136.34	2189.84±192.23	2496.49±51.11	67.52±10.21	27.23±8.07	2998.6±174.5	23.62±1.23	2.82±0.86
Group 2	1693.40±196.81	2390.96±75.34	2070.31±90.90	53.55±6.64	18.46±7.82	2563.2±504.9	24.76±0.82	2.61±0.82
Group 3	1925.3±0	2346.99±0	2322.35±0	78.72±0	28.19±0	1187.1±0	19.52±0	7.26±0
Group 4	1815.33±60.61	2019.72±226.55	2541.46±39.98	65.70±7.42	26.90±11.93	27.9.4±2.9.8	22.21±1.23	3.54±1.25
Group 5	1862.56±97.76	2344.29±66.70	2478.69±44.49	55.39±4.96	32.99±8.01	2660.1±217.9	21.34±0.81	2.75±1.05

The analysis of water explained that group 1 showed high concentration of salinity (41.15±1.99 ppt) and zinc (0.58±0.06 ppm) while Group 2 exhibited high value of dissolved oxygen (4.40±0.38 g/L) while low values of conductivity and total dissolved solids (49.53±6.05) (30.70±3.99 ppm) respectively. In Group 3 most of the parameters showed maximum values including, pH (8.1±0.11), viscosity (9.25±0.21), cobalt (0.51±0.001 ppm) and manganese (4.395±0.22 ppm) with lower mean values of salinity (33±1.95 ppt) and iron (0.056±0.015 ppm). In comparison group 4 revealed minimum values of dissolved oxygen (1.89±0.71 g/L), pH level (6.83±0.47), zinc (0.06±0.02 ppm) and cobalt concentration (0.31±0.10 ppm). The maximum conductivity (64.05±2.69), total dissolved solids (39.84±2.57) and temperature (26.23±1.55 ºC) was recorded from this group. The least values of temperature (22.76±1.07 ºC) and viscosity (8.49±0.04) were recorded in group 5. Group 6 was also an important group that exhibited the lowest concentration of manganese (3.85±0.91 ppm) maximum levels of iron (0.61±0.10 ppm), cobalt (0.51±0.01ppm) and chromium (0.62±0.15 ppm). On the other hand, the value of specific gravity (1.03±0) was almost same in all groups. (Table 3).

Table 3: Mean values of physico-chemical properties of mangrove water in groups

Parameters	Salinity	Conductivity	TDS	DO	Temperature	pH	Specific gravity
Group 1	41.15±1.99	60.31±2.46	39.45±1.39	2.31±0.43	24.48±1.51	7.48±0.21	1.03±0
Group 2	36.80±1.54	49.53±6.05	30.70±3.99	4.40±0.38	25.80±2.03	8.04±0.50	1.03±0
Group 3	33±	52.1±33.2	33.2±0	3.87±0	26±8.1	8.1±0	1.03±9.25
Group 4	41.13±2.40	64.05±2.69	39.84±2.57	1.89±0.71	26.23±1.55	6.83±0.47	1.03±0
Group 5	38.44±2.50	56.15±2.28	36.98±2.41	2.68±0.51	22.76±1.07	7.38±0.30	1.03±0
Group 6	40.13±1.39	63.33±2.65	38.17±2.07	2.02±0.98	25.60±1.14	7.07±0.09	1.03±0
Parameters	**Viscosity**	**Fe**	**Zn**	**Co**	**Cr**	**Mn**	
Group 1	8.54±0.14	0.58±0.12	0.58±0.06	0.42±0.06	0.48±0.11	4.28±0.29	
Group 2	8.76±0.24	0.58±0.05	0.17±0.07	0.46±0.03	0.59±0.22	3.95±0.30	
Group 3	9.25±0	0.056±0.0154	0.515±0.15	0.515±0	0.15±0	4.395±0	
Group 4	8.79±0.24	0.55±0.02	0.06±0.02	0.31±0.10	0.42±0.15	4.01±0.22	
Group 5	8.49±0.04	0.38±0.08	0.20±0.05	0.38±0.06	0.49±0.12	4.24±0.40	
Group 6	8.99±02.8	0.61±0.10	0.14±0.05	0.51±0.01	0.62±0.15	3.85±0.91	

Ordination

The results of principal component analysis (PCA) of stands are given in Table 4. The first principal component accounts for 33% of the total variance. While the second component accounts for 20.36% of the total variance. The third component represented 18.20 % of the total variability. The first three components together accounted for 71.57% of the total variability. The first component is primarily controlled by tree height, number of pneumatophores, height of pneumatophores and density/ha. The second component is mainly controlled by leaf area, basal area, density/ha and height of pneumatophores whereas the third component is proscribed by density/ha, basal area, leaf area and number of pneumatophore.

Table 4: Results of principal component analysis showing Eigen value percentage variance, cumulative percentage variance, first six ranked eigenvector coefficients and vegetation parameters

Axis	Eigen value	% of Variance	Cum.% of Variance	Eigenvector coefficient	Associated variables
1	1.980	33.001	33.001	0.61	Tree height
				0.55	No. of Pn
				0.46	Height of Pn
				0.29	Density/ha
2	1.222	20.364	53.365	0.74	Leaf Area
				0.51	Basal Area
				0.22	Density/ha
				0.11	Height of Pn
3	1.092	18.205	71.569	0.65	Density/ha
				0.30	Basal Area
				0.16	Tree height
				-0.02	No. of Pn

Note: Pn=Pneumatophores

The PCA stand ordinations axes 1 and 3 and axes 2 and 3 are shown in Figure 2 and 3 respectively. The six main groups which derived from the Ward's cluster analysis were superimposed on PCA ordination at axes 1 and 3 and axes 2 and 3. No overlapping of groups was seen in all groups, the groups were separated out clearly on these axes. However, these groups were divided efficiently in PCA ordination on axes 1 and 3 i.e. only one stand (28) was located in group 3 at the right of the upper side at axis 1 and 3 whereas on axis 2 and 3 this laid at the upper central part of the ordination.

Interestingly, the ordinations of axes 1 and 3 and axes 2 and 3 exhibited almost continuous distribution of stands across the ordination planes. *A. marina* was found as a dominant species in 26 stands out of 28. All main groups were separated on the basis of density/ha. All the stands in group 1 are located at the right side on axis 1 and 3 and on 2 and 3 it occupied central position. Group 2 consisting of four stands considered the less polluted areas found towards right in the bottom. Group 3 is the impure stand dominated by *R. mucronata* and the co-dominant species is *A. marina.* This group was located upper at group 1 at both the ordination plane. Group 4 was found among the groups 2, 5 and 6 at the lower central part of the axis 1 and 3 and 2 and 3. Group 5 was to the left of the ordination whereas group 6 was situated at the central lower side of the ordination plane.

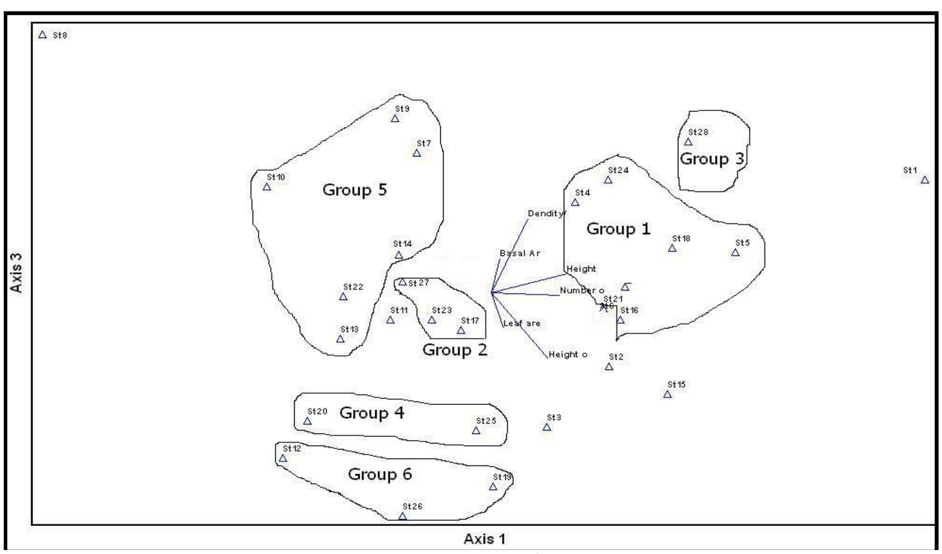

Figure 2: Principal component analysis of total vegetation parameters

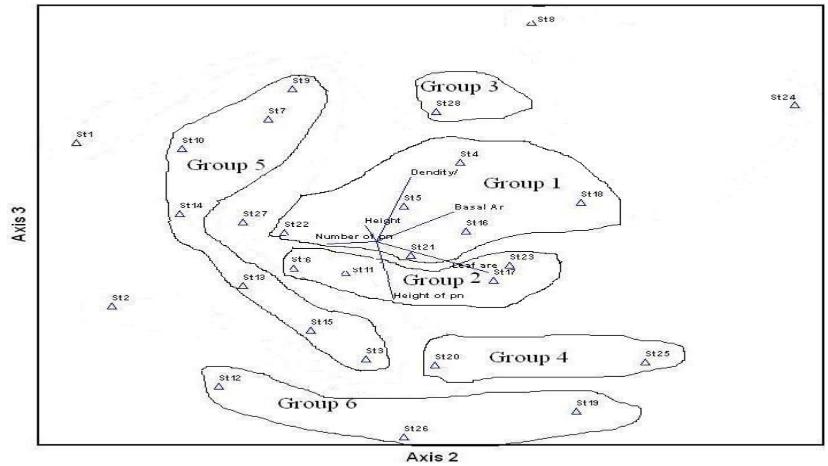

Figure 3: Principal Component Analysis of total vegetation parameters.

Correlation of Ordination Axis with Physico-chemical Variables

It was stated that physico-chemical factors influencing mangrove distribution were inferred from the ordination patterns. The correlation of ordination axes with physical variables of water and soil are given in Table 5 to 9. Ordination axis 1 was positively correlated with water and soil pH ($P<0.05$). The physical parameters of both soil and water were plot against ordination axis 2 and 3 which showed positive correlation with conductivity ($P<0.05$) and temperature of water at ($P<0.01$) probability level. The viscosity of water and total dissolved solids of soil were also correlated on axis 3 at $P<0.05$ and $P<0.001$ respectively. The correlation coefficient between soil and nutrients and the axis of PCA ordination described that magnesium was correlated at $P<0.05$ while Sulphate and nitrate were significantly correlated on axis 2 at $P<0.01$. The heavy metal analysis of water and sediments disclosed that cobalt in water and chromium in soil were significantly correlated at $P<0.05$ on both axes 2 and 3.

Table 5: Correlation coefficient between mangrove water and the first three axes of the PCA stand ordination

Variables	Axes 1		Axes 2		Axes 3	
	r-value	Significance	r-value	Significance	r-value	Significance
Salinity	0.11	Ns	0.23	ns	0.13	Ns
Conductivity	0.25	Ns	0.35	*P*<0.05	0.35	*P*<0.05
TDS	0.16	Ns	0.12	ns	0.04	Ns
DO	0.15	Ns	0.17	ns	0.09	Ns
Temp	0.25	Ns	0.50	*P*<0.01	0.47	*P*<0.01
pH	0.38	*P*<0.05	0.11	ns	0.00	Ns
Specific gravity	0.11	Ns	0.29	ns	0.00	Ns
Viscosity	0.03	Ns	0.15	ns	0.35	*P*<0.05

Note: TDS= total dissolved solids, DO= dissolved oxygen, Temp=temperature, r = Correlation coefficient. ns = Non signifiant

Table 6: Correlation coefficient between heavy metals of mangrove water and the first three axes of PCA stand ordination based on the data of circular plots vegetation

Variables	Axes 1		Axes 2		Axes 3	
	r- value	Significance	r- value	Significance	r- value	Significance
Fe	0.24	Ns	0.03	ns	0.12	Ns
Zn	0.06	Ns	0.24	ns	0.30	Ns
Co	0.25	Ns	0.40	*P*<0.05	0.35	*P*<0.05
Cr	0.23	Ns	0.19	ns	0.23	Ns
Mn	0.10	Ns	0.07	ns	0.17	Ns

Note : r = Correlation coefficient. ns = Non signifiant

Table 7: Correlation coefficient between edaphic factors and the first three axes of PCA stand ordination based on the data of circular plots vegetation

Variables	Axes 1		Axes 2		Axes 3	
	r- value	Significance	r- value	Significance	r- value	Significance
OC	0.101	ns	0.037	ns	0.055	Ns
MWHC	0.042	ns	0.022	ns	0.210	Ns
pH	0.383	*P*<0.05	0.111	ns	0.004	Ns
Salinity	0.036	ns	0.141	ns	0.231	Ns
Conductivity	0.218	ns	0.386	*P*<0.05	0.449	*P*<0.01
TDS	0.229	ns	0.308	ns	0.460	*P*<0.01

Note: OC=organic compound, MWHC= mean water holding capacity, TDS=total dissolved solids, r = Correlation coefficient. ns = Non signifiant

Table 8: Correlation coefficient between soil nutrients and the first three axes of PCA stand ordination

Variables	Axes 1		Axes 2		Axes 3	
	r-value	Significance	r-value	Significance	r-value	Significance
Sulphate	0.118	Ns	0.449	$P<0.01$	0.151	ns
Nitrate	0.195	Ns	0.475	$P<0.01$	0.017	ns
Sodium	0.222	Ns	0.090	ns	0.189	Ns
Pottassium	0.169	Ns	0.306	ns	0.175	ns
Calcium	0.115	Ns	0.171	ns	0.190	ns
Magnesium	0.346	$P<0.05$	0.024	ns	0.039	ns

Note : r = Correlation coefficient. ns = Non signifiant.

Table 9: Correlation coefficient between soil heavy metals the first three axes of PCA stand ordination

Variables	Axes 1		Axes 2		Axes 3	
	r-value	Significance	r-value	Significance	r-value	Significance
Zinc	0.303	Ns	0.246	ns	0.004	Ns
Iron	0.136	Ns	0.035	ns	0.216	Ns
Cobalt	0.157	Ns	0.049	ns	0.115	Ns
Chromium	0.212	Ns	0.374	$P<0.05$	0.324	$P<0.05$

DISCUSSION

It has been pointed out by Greig-Smith, (1983) that the two basic techniques viz. classification (clustering) and ordination are complementary to each other though fundamentally applied for different purposes. Multivariate analysis was exceedingly useful in exposing the underlying group structure on the basis of density/ha as a major prevailing factor in the data structure. PCA ordination is an important and effective multivariate analysis tool for ordinating homogeneous community data (McCune and Mefford, 2006). The gradational nature of these data was explored through Principal Correspondence Analysis (PCA) by following Fasham (1977).

The number of individual/ha in group 1 ranked first in accordance with density/ha of mangroves species *A. marina.* The trees in Sandspit 1, Sandspit 4, Chara creek (Aziz point), Ganglaro creek, Sukro Creek, Korangi Creek, Korangi area, and Dubbo Creek were higher than basin mangrove forests. It is necessary to mention that this group contains mixed conditions of the forests from less polluted to higher polluted areas. Most of the areas are away from the interruption of inhabitants due to unavailibity of resources to reach in these areas. However, these areas also showing the heavy metal pollution but among them the higher concentration of iron provides the reasons of the maximum density, Basal area m^2/ha, height of pneumatophore and leaf area. Sediment and water characteristics are the most important environmental factors directly affecting mangrove productivity and structure However, the concentration of the iron in present study was lesser than Ismail, (2002) in the same mangrove areas. Iron is an essential element which form an iron plaque over the sediment layers, according to Lacerda (1997) formation of plaque controls the uptake of ions present in saline sediments. On the other hand, Otte *et al*. (1987) stated that iron plaque behaves as a geochemical barrier against the uptake of trace metals by roots in mangroves while St-Cyr and Crowder, (1990); Tanizaki, (1993) reported that iron plaque fixes most of the trace metals deposits on the outer cortex of the roots and resists to enter in the root tissues. The maximum height of pneumatophores in this group suggested the most efficient mechanism of these aerial roots to neutralize the effects of heavy metals as reported by Scholander *et al*. (1962). Stand density referred many trees while basal area referred the presence of large amount timber in these particular mangrove forests. Group 2 ranked second with respect to density/ha close to the basin forests with minimum tree height. All the creeks (Gharo Creek, Chhan Waddo Creek, and Dubbo Creek) and a channel (Budgashi Channel) found in this group were the high land areas which provide a protected environment to the mangrove forests from erosion and heavy tidal influence. The logging of the trees is prohibited in these areas which is one of the basic reason of high density. Though the tree height was owing to least concentration of sodium, calcium and magnesium. Reef *et al*. (2010) stated that nutrient limitation is correlated with multiple factors, including sediment, tidal range and substrate type. In all plant communities nutrient availability is an important driving variable influencing community structure (Grime, 1979; Chapin, 1980; Tilman, 1987). This is also the case for mangrove forests (Boto and Wellington, 1983). According to Reef *et al*. (2010) the nutrients most likely to limit growth in mangroves species similarly, Ukpong, (1997) showed that nutrient availability is one of the dominant components influencing mangrove vegetation performance.

Group 3 was the isolated group with single stand at Kuppa Wali having highest density/ha and basal area m^2/ha of *R. mucronata* while *A. marina* in this stand recorded as co-dominant species with least individuals/ha. The number of trees/ha of *R. mucronata* was higher than fringe forests while the trees of associated species *A. marina* lower than riverine forests During the whole study this is the only place where *A. marina* and *R. mucronata* were co-existing may be due to inconsistent zonation pattern of lagoon (Saifullah and Rasool, 2002). *A. marina* is found at the front line followed by *R.mucronata* in the middle and according to Saifullah and Rasool, (2002) this type of zonation provides a better chance to *R.mucronata* to survive and flourish. Similar type of zonation was also reported by Kogo *et al*. (1980), secondly least salinity level measured from this site, may be favorable for the growth of the *R. mucronata* seedling. Kathiresan and Thangam, (1990) stated this species shows better growth in salinity ranged upto 30ppt. The density in group 4 lower than groups 1, 2 and 5 but higher than riverine forests type which is characterized by finest growth conditions (Lugo and Snedaker, 1974, Cintron *et al*., 1985). Brown and Lugo, (1982) reported riverine system as a more productive system than fringe, basin and dwarf systems. These areas are anthropogenically disturbed including high rate of cutting trees and grazing. Maximum number of pneumatophores in this group might be due to the fact of the high values of conductivity and total dissolved solids which provide better chance to exchange available materials in pneumatophores. The high values of these conductivity and TDS relate with high concentration of calcium ion. Tariq *et al*. (2008) reported that the plants with proper nutrients are able to produce new roots to replace the older roots. Coultas and Calhoun, (1976) reported much higher values of conductivity in Florida attributed to the high values of limestone underlying the mangrove sediments.

The density of *A. marina* in group5 positioned third, near to basin forests while the maximum basal area m^2/ha was lower than fringe but higher than dwarf forests. The major stands of this group located at two major creeks systems; Gharo and Korangi creeks. Siddiqui, (2001) also reported the dense growth of mangrove in Korangi creek this might be due to the convenience of effluents from cattle colony rich with nutrients. The sites possessed high rate of water holding capacity, organic matter, sulphate and nitrate which might be favorable for the growth of the mangrove species. All these parameters are inter linked, Lacerda and Abrao, (1984) proposed that in the sediments heavy metal accumulation is mainly controlled by its greater absorbing capacity while Ismail, (2002) explained the nature of the organic matter to reduce the state of the sediments by producing high concentration of hydrogen sulphide. The reduction of sulphate to sulphide would result in production of ammonia reported by Haynes and Lyons, (1982).

It would be possible that ammonia is converted into nitrate by nitrifying bacteria; the higher pH (alkalinity) also favored this result. Argon, (1986) reported the sinking behaviour of sulphide for heavy metals while Haghiri, (1974) explained the chelating property of organic matter which combines with certain groups of heavy metals to fixes them in the sediments. According to Hudson, (1994) water holding capacity is greater with high organic matter. It is same in the case of the present study the organic matter stabilizes soil structure which causes an increment in volume as well as the size of the pores. It was suggested that organic matter and water holding capacity is beneficial for the increment in basal area of the mangrove trees. Reduce height of pneumatophores in this group may be due to the high rate of organic matter which reduces the consumption of oxygen. According to Nazim *et al.* (2010) oxygen is a demanding factor which gave a profound effect on the growth of pneumatophores. Among three stands of group6 *R. mucronata* grows as a dominant species with associated species *C. tagal* in only Baloch Bhira while Phitti creek and China creek consist monospecific stands of *A. marina*. The presence of *R. mucronata* and *C. tagal* in Baloach Bhira is more surprising because they are absent in the adjacent site s of Kalmat Hor, Gwatar bay and eastern part of the Indus delta (Saifullah and Rasool, 2002). Even these species also not found in the adjacent Iranian territory of Qeshir island (Kogo *et al*., 1980; Spalding *et al*., 1997). The associated species grows with a low profile due to small density and size of the trees. Another reason may be attributed to the unavailability of fresh water, logging and siltation which are major threats to the mangroves at this particular site (Alizai *et al*., 1988). However, there are two rivers viz. Porali river and Winder river between these two Porali river is the largest river compared to any other rivers in Balochistan (Verheijen, 1998). The absence of rainfall in the area converted into a river of sand (Hussain, 1998). According to Mirza *et al*. (1982) the total mangrove cover in the lagoon is about 3000 ha which amounts 25% of the total area but has already reduced due to high rate of sedimentation with the last century.

The number of trees of *A. marina* were lower than riverine forest due to pollution because these areas are majorly concerned as a source of pollutants (Ismail, 2002). The least concentration of organic matter and water holding capacity also enhance the rate of heavy metals accumulation in trees. The maximum tree height of the *A. marina* was recorded in this group might be possible due to high concentration of zinc and chromium. The results presented here seem to support the findings of Zheng *et al*. (1997) who strongly opposed to plant mangrove seedlings in Zinc polluted sites because seedling secretes certain types of organic acids that may increase the solubility of the metals resulting in high rate of mortality due to Zn toxicity. Principal component analysis is geared to ecological data sets and secondly the tendency to compress the axis ends relative to the middle, is also corrected in the PCA. The sites have higher resemblances with respect to the variables therefore all the sites showed a same clustered distribution in the ordination planes. The Eigen value forms a descending series with first component (axis) explaining the maximum variance and a maximized efficiency, utilizes all the correlations within stands. The principal reason of obtaining strong, weak or no correlation with many of the environmental factors seems to be the disturbance of vegetation due to natural or anthropogenic activities.

CONCLUSION

The major gradients that were disclosed by PCA ordination indicates some degree of discontinuity as the groups emerging from cluster analysis segregated in ordination plane. The first component can be treated as an amalgam of associated variables tree height, number/height of pneumatophores and density/ha. The application of multivariate techniques i.e. classification and ordination have resulted in a clear demonstration of vegetation pattern in study area in quantitative terms that linked to certain physico-chemical parameters.

Acknowledgement

The authors are grateful to Prof. Jonathan Palmer, Director Gondwana Tree-ring Laboratory for their valuable comments on the early version of this manuscript.

Conflict of Interest

Authors declared no conflict of Interest.

REFERENCES

Alizai, S. A. K., Aii, J. and Mirza, M.I. (1988). Role of satellite remote sensing in monitoring sedimentation processes lagoons along the coast of Baluchistan, Pakistan. In: Marine Science of the Arabian Sea (Eds. Thompson and Tirmizi): 359-372.

Anderson, M.J. (2001). A new method for non-parametric multivariate analysis of variance. *Austral Ecology* 26(1): 32-46.

Argon, G.T. (1986). Estudo geoquimico de metais pesados em sediments da planicie de mare da Enseada das Garcas. Baia de Sepetiba. RJ.T.Mest., Inst. Quimica, Univ.fed. Fluminense. 135.

Berrow, M.L. and Stein, W.M. (1983). Extraction of metals from soils and sewage by refluxing with aqua regia. *Analyst* 108: 277-285.

Boto, K.G. and Wellington, J.T. (1983). Nitrogen and phosphorus nutritional status of a northern Australian mangrove forest. *Marine Ecological Progress Series* (11): 63-69.

Brown, S. and Lugo, A.E. (1982). A comparison of structural and functional characteristics of saltwater and freshwater forested wetlands: 109-130. In B. Gopal, R.E. Turner, R.G. Wetzel & D.E. Whigham (Eds.). *Wetlands ecology and management*. Proc. 1st Int. Wetlands Conf., New Delhi, India.

Chapin, F.S., III, (1980). The mineral nutrition of wild plants. *Annual review of Ecology and Systematizes* 11: 233-260.

Chapman M.G., Underwood A.J., Skilleter G.A. (1995) Variability at different spatial scales between a subtidal assemblage exposed to discharge of sewage and two control sites. *Journal of Experimental Marine Biology and Ecology* 189: 103-122.

Cintron, G., A. E. Lugo and R. Martinez. 1985. Structural and functional properties of mangrove forests. Pp. 53-66. In: The Botany and Natural History of Panama. W. G. D Arcy and M. D.A. Correa. (Eds.). Missouri Botanical Garden, Saint Louis, MO.

Coultas, C. L and F. G. Calhoun. 1976. Properties of some tidal marsh soils of Florida. *Soil Science Society of American Journal* 40: 72-76.

Faith, D.P., Dostine, P. L., Humphrey, C.L. (1995). Detection of mining impacts on aquatic macroinvertebrate communities: results of a disturbance experiment and the design of a multivariate BACIP monitoring program at Coronation Hill, N. T. *Australian Journal of Ecology* 20: 167-180.

Fasham, J.J.R. (1977). A comparison of non-metric multidimensional scaling, principal components and reciprocal averaging for the ordination of simulated coenoclives and coenoplances. *Ecology* 58: 551-561.

Glasby, T.M. *(*1997*)* Analysing data from post-impact studies using asymmetrical analyses of variance: a case study of epibiota on marinas. *Australian Journal of Ecology* 22: 448-459.

Gray, J.S., Clarke, K.R., Warwick, R.M., Hobbs, G. (1990) Detection of initial effects of pollution on marine benthos: an example from the Ekofisk and Eldfisk oilfields, North Sea. *Marine Ecology Progress Series* 66: 285-299.

Greig-Smith, P. (1983). Quantitative Plant Ecology, 3rd ed. Blackwell scientific, Oxford: 359.

Grime, J.P. (1979). Plant strategies and vegetation processes. Chichester. Wiley: 222.

Haghiri, F. (1974). Plant uptake of cadmium as influenced by cation exchange capacity organic matter, zinc and soil temperature. *Journal of Environment*. *Quabit* 3: 180-183.

Haynes, M. E. and Lyons, W.M.B. (1982). Biogeochemistry of nearshore Bermuda sediments. I. Sulfate reduction rates and nutrients generation. *Marine Ecology Progress Series* 8:87-94.

Hudson, B.D. (1994). Soil Organic-Matter and Available Water Capacity. *Journal of Soil Water Conservation* 49:189-194.

Hussain, S. (1998). The river of sand. The Financial Post, Karachi 3rd March.

Ismail, S. (2002). Assessment of heavy metal pollution in mangrove habitat of Karachi and vicinity. Thesis University of Karachi.

Kathiresan, K. and B. L. Bingham. (2001). Biology of mangroves and mangrove ecosystems. *Advances in Marine Biology* 40: 118- 251.

Kathiresan, K. and, T.S. Thangam. (1990). Effect of phenolics on growth of viviparous seedlings of *Rhizophora apiculata* Blume. *Geobios* 17: 142-143.

Kelaher, B.P., Chapman, M.G., Underwood, A.J. (1998). Changes in benthic assemblages near boardwalks in temperate urban mangrove forests. *Journal* of Experimental *Marine Biology* and *Ecology* 228: 291-307.

Kogo, M., Sato, K., Takatrki, S. and Takashi, R.. (1980). An ecological survey on the mangrove forestof Persian (Arabian) Gulf and Pakistan. Japanese co-operation center for the Middle East: 96.

Lacerda, L.D. (1997). Trace metals in mangrove plants: why such low conccentration? In mangrove ecosystem dtudies in Latin America and Africa (B. Kjerfive, L.D. Lacerda and E.S. Drop, eds) 171-178, UNESCO, Paris.

Lacerda, L.D. and Abrao, J.J. (1984). Heavy metal accumulation by saltmarsh intertidal sediments. *Revista Brasileira de Botânica* 7: 49-52.

Lugo, A.E and Snedaker, S.C. (1974). The ecology of mangroves. *The Annual Review Ecology, Evolution, and Systematics 5*: 38-64.

McCune, B. and M.J. Mefford. (2006). Multivariate Analysis of Ecological Data. PC. ORD Version 5.10 MjMSoftware, Gleneden Beach, Oregon, U.S.A.

Mendoza, A.B. and Danilo, P.A. (2001). Mangrove structure on the eastern coast of Samar Island, Philippines. In: D.E stott. R.H. Mohtar and G.C. Stemhardt (eds): 423-42.

Mirza, M.I., Hasan, M.Z., Akhtar, S., Ali, J. (1982). Identification and Area Estimation of mangrove vegetation in Indus Delta using Land sat Data. In mangroves of Pakistan, proceding of national workshop on mangroves held at Karachi 8-10 of August 1983, PARC. Islamabad, 19-21.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Method of Vegetation Ecology. John Wiley and Sons, New York.

Nazim, K., M. Ahmed, M. U. Khan, N. Khan, M. Wahab and M. F. Siddiqui. 2010. An assessment of the use of *Avicennia marina* Forsk Vierh. To reclaim water logged and saline agricultural land. *Pakistan Journal of Botany* 42(4): 2423-2428.

Oliver I. & Beattie A. J. (1996). Designing a cost-effective invertebrate survey: a test of methods for rapid assessment of biodiversity. *Ecological Applications* 6: 594-607.

Otte, M. L., Buijs, E.P., Riemer, L., Rozema, J.and Brokeman, P.A. (1987). The iron plaque on the roots of salt marsh palnts a barrier to heavy metal uptake. 405-409. In: S.E. Lindberg and T.C. Hutchenson (eds). Proc. 6th Inter. Conf. Heavy metals in the environment, New Orleons Lousiana.

Quinn, G.P., Lake, P.S., Schreiber, S.G. (1996). Littoral benthos of a Victorian lake and its outlet stream: spatial and temporal variation. *Australian Journal of Ecology* 21: 292-301.

Reef, R., Feller, I.C. and Lovelock, C.E. (2010). Nutrition of mangroves. *Oxford Journals Life Sciences Tree Physiology* 30(9):1148-1160.

Saifullah, S.M and Rasool, F. (2002). Mangroves of Miani Hor lagoon on the north Arabian Sea coast of Pakistan. *Pakistan Journal of Botany* 34(3): 303-310.

Savage, T. (1972). Florida mangroves as shoreline stabilizers. Florida Department of Natural Resources professional paper: 19.

Scholander, P.F., Hammel, H.T., Hemmingsen, E. and Garey, W. (1962). Salt balance in mangroves. *Plant Physiology* 37: 722-729.

Siddiqui, P.J. A. (2001). Mangroves play a role in sustenance of a balances ecosystem. In: Coastal zone management and Environmental impact assessment. (eds.) Azra meadows and Peter Meadows. (DFID) The British Council.

Skilleter, G.A. (1996). Validation of rapid assessment of damage in urban mangrove forests and relationships with Molluscan assemblages. *Journal of the Marine Biological Association UK* 76: 701-716.

Spalding, M., Blasco, F. and Field, C. (1997). *World Mangrove Atlas.* ISME Okinawa, Japan. 178.

St-Cyr, L. and Crowder, A.A.. (1990). Manganese and Copper in the root plaque of Phragmites australis (cav.) Trin ex Stendel. *Soil Science* 149: 191-198.

Tanizaki, G.K.F. (1993). Biogeoquimica da rizosfera de palnts de mangue. Tesade Mestrado, Dept. Geoquimica, Universidade Federal Fluninense, Niteroi.

Tariq, M., Dawar, S., Mehdi, F.S. and Zaki, M.J. (2008). Fertilizers In combination With *Avicennia Marina* In The Control Of Root Rot Diseases Of Okra And Mung Bean *Pakistan Journal of Botany* 40(5): 2231-2236.

Tilman, D. (1987). Secondary succession and the pattern of plant dominance along experimental nitrogen gradients. *Ecological Monographs* 57: 189-214.

Ukpong, I.E. (1997). Vegetation and its relation to soils nutrient and salinity in the Calabar mangrove swamp, Nigeria. *Mangroves and Salt Marshes* 1: 211-218.

Verheijen, O. (1998). *Cort~tnunity Irrigation Systetns in the Province of Balochistan.* Balochistan Community Irrigation and Agriculture Project. Halcrow Euroconsult Nespak Technoconsult, Quetta, Balochistan. 85.

Ward, J.H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association 58(301):236-244*

Warwick, R.M., Carr, M.R., Clarke, K.R., Gee, J.M., Green, R.H. (1988). A mesocosm experiment on the effects of hydrocarbon and copper pollution on a sublittoral soft-sediment meiobenthic community. *Marine Ecology Progress Series* 46: 181-191.

Zheng, S., Zheng, D., Liao, B. and Li, Y. (1997). Tideland pollution in Guangdong province of China and mangrove afforestation *Forest Resources* 10(6): 639-646.