Pak. j. sci. ind. res. Ser. B: biol. sci. 2018 **61B**(1) 21-31

Assessment of Vegetation-Edaphic Correlation of Wetland Complex of Soon Valley, Pakistan using Multivariate Techniques

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(received September 23, 2016; revised December 6, 2016; accepted December 20, 2016)

Abstract. Vegetation-edaphic correlation was studied to abserve ecological relationship of plants. Because of the interrelationship of environmental variables various ordination techniques i.e., Two-way Indicator Species Analysis (TWINSPAN), Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA)) were employed to reveal the inherent pattern on visual inspection. Total 36 herbaceous species belonging to 16 families were identified in the area of Ucchali wetland complex, Soon Vally, Khusab, Pakistan, with *Cynodon dactylon* as dominant species owing to its high tolerance to prevailing environmental conditions. Results of CCA exposed elevation, organic matter and pH to be the most influencing factors in growth and distribution of flora of the area. Different analyses such as biplots, data attribute plots and pie symbols plots were accomplished for the species of the study area. Because of the induced change, various non-native and invasive species were also recorded in the area which might contribute to further altering the range ecology of the area. Apart from promoting sustainable use of natural resources in Ucchali Wetlands Complex (UWC); ecological integrity of the Ramsar sites must be conserved and improved through ecological interventions related to illicit cutting of forest, unsustainable utilization of water resources, municipal pollution, agricultural intensification, etc.

Keywords: TWINSPAN, DCA, CCA, multivariate techniques, vegetation, wetland complex

Introduction

The association between vegetation and environment is a very significant topic of plant ecology. A huge number of environmental variables are correlated as a result of an overriding influence; it is often complicated to conclude which factors are in fact causing vegetation patterns (Tavili *et al*., 2010). In the field of ecology, study of vegetation in relation to different environmental factors with the use of ordination technique and classification method has become well acknowledged and to study the complex nature of plant communities various multivariate techniques are available (Ali and Malik, 2010). A multivariate analysis integrating ecological, physical and socio-economic characteristics to investigate flora of the area has been well researched and numerous approaches and techniques exist to study their association. For the classification of flora according to ecological liking a computer based software application i.e. TWINSPAN exists (Ahmad *et al*., 2014a; 2014b; 2014c; Hill, 1979), while for the phytosociological ordination an indirect analysis technique i.e. DCA is widely used owing to its inclusive results (Urooj *et al*., 2015; Kent and Coker, 1996). CCA is a more modern day technique to study the correlation between flora and environmental variables in addition to its comprehensive results in the form of graphs and pie charts (Ahmad, 2011; Ter Braak and Smilaur, 2002). The study on multivariate and statistical analysis is not the only method because various researches from international and national level have already been successfully conducted for classification of flora (Urooj *et al*., 2015; Ahmad and Quratulain, 2011; Ahmad, 2010; Xiaoni *et al*., 2007). Studies related to ethno medical survey (Ghani *et al*., 2014), estimation of nutrients in medicinal plants (Ghani *et al*., 2012) and evaluation of biomass and carrying capacity (Saleem and Mirza, 2012) has already been conducted in Soon Valley of Pakistan. However the vegetation associated with environmental variables has not been quantitatively correlated in the region. Hence, this study aims to examine the relationship between species distribution with the changing environmental factors and gradients by using ordination technique.

Ucchali wetlands complex located in a cup shaped valley called Soon Valley in district Khushab of Pakistan. The complex has three Ramsar sites surrounded by mountains which are Ucchali, Khabeki and Jahlar. It extends from Khabeki in the east to Sakesar in the west and covers approximately an area of 745 km^2 (Fig.1). The area is sub-humid, sub-tropical and has suffered

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drought in the past. The area is the habitat to globally threatened waterfowl species. Owing to the increased agricultural practices the area is suffering decrease in its native species. These native species define the ecology of the region. Understanding vegetation and their relationship with environmental variables will serve as important information to land managers in managing, reclaiming and developing ecosystems. It will also provide a conceptual basis for the description of resource potential and ecological integrity of the area.

Materials and Methods

Vegetation sampling. Terrestrial vegetation from the UWC was sampled in the month of September and March, when most of the species were expected to be growing. For the study 150 quadrates were laid by stratified random sampling approach (Kent and Coker, 1996). The quadrate size of 1x1 m^2 was chosen for herbaceous and shrubby vegetation, since most plants had stunted growth. Domin cover scale with modifications by Bailey and Poulton (1968) was used to interpret visually estimated species cover value (Mueller-Dombois and Ellenberg, 1974). Metadata for each quadrate i.e., species attributes along with latitude, longitude and elevation of each quadrate were also recorded using Garmin eTrex GPS. Plant specimens which were unidentified in field were collected and identified.

Soil sampling. Soil samples 6-10 cm deep from each of the fifty quadrats was collected in plastic bag with the help of spade. The coded sample bags were approx 1 kg for obtaining relevant data on physical and chemical characteristics.

Physicochemical analysis of soil. Soil physicochemical properties play a very significant role in spatial distribution of vegetation community (Tavili *et al*., 2010). For this purpose soil was air dried after mixing it thoroughly and then dried samples were sieved to remove particles (rock, debris, gravel) larger than 2 mm. These subsamples were then retained for moisture, pH, texture, moisture, EC, OM and macronutrients (N, P and K) and micronutrient (Zn, Cu, Fe and Mn) analysis. Soil analysis was conducted in the laboratory of FJWU.

EC and pH were determined by Crison MM40+ portable meter. Walkley (1947) titrimetric method was used for determination of organic matter in soil. Soil texture was analyzed with the help of Octagon Digital Sieve Shaker instrument (Brady, 1990) and Allen (1974) method was employed for finding out the moisture in soil. Phosphorus was analyzed by Olsen's method using spectrophotometer (Nathan and Gelderman, 2012). Potassium and micronutrients in soil were determined by using atomic absorption spectrophotometer (Ehi-Eromosel *et al*., 2012). Nitrogen in soil was analyzed by first digesting the soil and then titration of digested solution against sulphuric acid prior to addition of an indicator (Urooj *et al*., 2016).

Ordination analysis. Ordination method was employed in this study for multivariate approach to analyze the vegetation clusters and affects of multiple environmental variables on these vegetation clusters simultaneously. The data sets pertaining to herbaceous and shrubby vegetation and edaphic factors were subjected to three type of multivariate analysis i.e., TWINSPAN (Two-way Indicator Species Analysis), DCA (Detrended Correspondence Analysis) and CCA (Canonical Correspondence Analysis).

Two way indicator species analysis (TWINSPAN). The first step in multivariate was to use the TWINSPAN technique to define distribution pattern of vegetation groups on the dataset having total of 150 stands. TWINSPAN is the most accepted hierarchical divisive clustering technique in community ecology (Leps and Smilauer, 2003). It constructs a two way table called dendrogram which expresses the relationship of sample and species (Hill, 1979). TWINSPAN using PCORD-5 application was used in this study to classify the species and sample data simultaneously along the UWC.

Detrended correspondence analysis (DCA). DCA is an indirect ordination technique used to mark out the similarities and differences between the vegetation compositions of quadrate samples (Hill and Gauch, 1980). It was used to correlate the change in vegetation pattern along the length of the underlying environmental gradients. It was used to ordinate clusters of species and to validate the accuracy of TWINSPAN results by species cluster formation.

Canonical correspondence analysis (CCA). CCA is a direct ordination technique and was used to analyze the relationship between environmental variables and identified vegetation species with the help of CANOCO 4.5 software (Xiaoni *et al*., 2007). The environmental variables for CCA analysis included pH, moisture, EC, OM, macronutrients (N, P and K) and micronutrients (Fe, Mn, Cu and Zn) of soil. The results of the ordination analysis were finally portrayed in the form of plots and charts for visual interpretation.

Results and Discussion

Species diversity. Native and wild species are usually considered as undesirable or sometimes harmful plants that intervene with the cultivated crops by taking away nutrients from soil. In fact these plants are vital component of biodiversity and play significant role in contributing to species diversity. Native species possess intrinsic value and some of them contain medicinal and nutritional value. These plants are very valuable and their loss may sometimes escalate to affect the entire ecosystem (Ruby *et al*., 2011). Total 37 plant species belonging to 16 families were identified around the area of the UWC (Table 1).

Many of the herbaceous and shrubby vegetation found in the study area serve as medicine and food source for local community (Ghani *et al*., 2014; Arshad, 2011) surveyed ethno medicinal plants of Soon valley. They reported that communities are dependent on them for their common day ailments and other value added products. Various medicinal plants of the region have also been categorized as rare included and endangered species therefore, serious efforts need to be put in for their sustainable and long term conservation. *Solanum nigrum* (black nightshade) of family Solanaceae is a herb or perennial shrub found in the area and useful for digestive disorders, corrosive ulcers and chronic skin diseases. *Chenopodium album* (fat hen, bathu) also

Table 1. List of species with families

Species	Families	Habitat	Species	Families	Habitat
Achyranthes aspera L.	Amaranthaceae	Tropical regions	*Fagonia olivieri* L.	Zygophyllaceae	Sandy soils over limestone or gravels
Alhagi maurorum	Fabaceae	Temperate and tropical regions	*Imperata c ylindrical* L.	Poaceae	Tropical and subtropical climates
Amaranthus viridis L.	Amaranthaceae	Heavy organic to very sandy soils	*Juncus* sp. L.	Juncaceae	Temperate regions
Brachiaria ramose (L.)	Stapf. Poaceae	Tropical regions	*Justacia adhatoda* L.	Acanthaceae	Moist places
Bromus pectinatus L.	Poaceae	Temperate regions	*Malva parviflora* L.	Malvaceae	All soil types
Buxus papillosa (C. K. Schn.)	Buxaceae	Tropical and sub tropical regions and are frost tolerant	*Parthenium hysterophorus* L.	Asteraceae	Semi-arid, subtropical, tropical and warmer temperate regions
Carissa opaca (Stapf.)	Apocynaceae	Tropical and sub tropical regions	*Peganum harmala* L.	Nitrariaceae	Dry deserted areas
Chenopodium album L.	Amaranthaceae	Soils rich in nitrogen especially wasteland	*Phyla nodiflora* L.	Verbenaceae	Marshy soil
Chrysopogon serrulatus (Hoch.)	Poaceae	Tropical and sub tropical regions	*Prosopis julifora* (Sw.)DC	Fabaceae	Sandy, rocky, poor and saline soils
Conyza bonariensis L.	Asteraceae	Tropics and Subtropics	*Rhynchosia minima* L.	Fabaceae	Pantropical grasslands
Cynodon dactylon (L.) Pers.	Poaceae	All soil types	*Setaria pumila* (Poir.)	Poaceae	Warm temperate areas
Datura innoxia	Solanaceae	Abondened and wasteland	*Solanum nigrum* L.	Solanaceae	Wooded areas
Desmostachya bipinnata (L.) Pers.	Poaceae	Temperate and tropical regions	*Solanum surattense* L.	Solanaceae	Coastal plains
Dichanthium annulatum	Poaceae	Moutain slopes and disturbed ground	*Suaeda fruticosa* L.	Amaranthaceae	arid and semi-arid salt marshes
Digitaria ciliaris (Retz.) Koel.	Poaceae	Tropical regions	*Typha domingensis* (Pers.)	Typhaceae	Temperate and tropical regions
Dodonaea viscose L. (Jacq.)	Sapindaceae	Cosmopolitan distribution	*Withania somnifera* L.	Solanaceae	Open places and distributed areas
Echinochloa colonum L.	Poaceae	Tropics	*Xanthium strumarium* L.	Asteraceae	Farmland, old lands, roadsides, wastelands, riverbanks and overgrazed pasturelands
Eragrostris papposa	Poaceae	Rocky places	*Ziziphus nummularia* (N. Burman)	Rhamnaceae	Deserted areas

found in the region belongs to family Chenopodiaceae and has been widely reported to be used for the treatment of urinary problems. *Withania somnifera* (ashwagandha) commonly cures weakness and is a blood purifier belonging to the family Solanaceae. *Peganum harmala* (harmal) heals stomach disorder while *Achyranthes aspera* (puthkanda) possess anti inflammatory properties. (Ghani *et al.*, 2014; 2012)

Ecologists have adapted multivariate techniques to analyze the site characteristics responsible for prevailing species of an area. The distribution of species and complex community structure is due to range of intermingling factors (Ahmad *et al*., 2014a; 2014b; 2014c). In arid and semi arid region, soil texture, pH, moisture, organic matter, macronutrients and micronutrients play significant role in growth, distribution and abundance of species (Zare *et al*., 2011).

Vegetation classification. Soil found in UWC upon analysis had loamy texture. Soil texture has profound influence on many soil properties and it affects the suitability of soil for many uses. This soil feature governs how nutrients, water and air move in soil (Brady and Weil, 1996).Vegetation of UWC from the 150 quadrates led to indentify 37 species of the area, which are presented in dendrogram in Fig.1 with the help of TWINSPAN method. The dendrogram formulates species into groups and communities on the basis of species close association and also prominently show up the dominant species. Hence, dendrogram was used to classify the vegetation in groups and sub groups. Each major group contained certain communities. These communities were named primarily after the dominant species in each community.

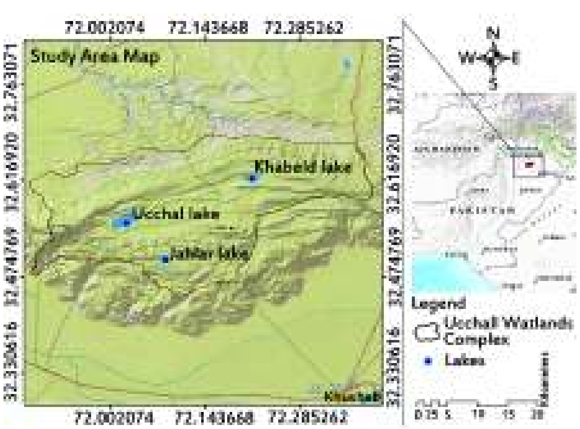

Fig. 1. Study area map of Ucchali wetlands complex.

DCA was also used as an indirect ordination to find main common gradient among species and to classify them in groups and communities. The close cluster of species represented their close association and common interest regarding life form and habitat. Likewise distances among points in the graph are taken as the degree of similarity or difference. Additionally these species clusters were also almost coherent with the results of TWINSPAN dendrogram. Some of the species had unique characteristics and were separate from the communities. These outlier species were *Digitaria ciliaris, Suaeda fruticosa* and *Ziziphus nummularia* (Fig. 2).

Community I, Alhagi-Typha is called after its dominant species *Alhagi maurorum* and *Typha domingensis,* belonging to Group I had total of eleven species. These eleven species included *Achyranthes aspera*, *Alhagi maurorum*, *Buxus papillosa*, *Withania somnifera, Xanthium strumarium*, *Typha domingensis*, *Buxus papillosa*, *Malva parviflora*, *Parthenium hysterophorus*, *Fagonia olivieri* and *Prosopis julifora.*

While **Community II**, under the same group I had four number of species i.e., *Amaranthus viridis*, *Imperata cylindrical*, *Chenopodium album* and *Solanum nigrum.* In addition this community was called as *Imperata-Solanum*.

Although **Community III** had *Bromus pectinatus*, *Datura innoxia*, *Chrysopogon serrulatus*, *Setaria pumila* and *Solanum surattense*. But owing to the abundance of *Chrysopogon serrulatus* and *Setaria pumila* in this community it was labeled as *Chrysopogon-Setaria*.

Commnunity IV had dominant species *Dichanthium annulatum* and *Carissa opaca* hence, called the name *Dichanthium - carissa*.

Community V named as *Juncus* - *Phyla* after its species *Juncus* sp. and *Phyla nodiflora,* while **Community VI** called *Justacia -Eragrostris* enclosed four other species (Fig.2). *Suaeda fruticosa* and *Ziziphus nummularia* also belonged to the same group I but were classified as outliers since they didn't form community with other species of the group.

group II communities enclosed total six species.

Commnunity VII had dominant species *Brachiaria ramose* and *Desmostachya bipinnata*. Species members of *Brachiaria-Desmostachya* included *Brachiaria ramose, Desmostachya bipinnata, Echinochloa colonum, Cynodon dactylon* and *Conyza bonariensis. Digitaria* *ciliaris*, the most abundant species in the area belonged to the same group but being an outlier remained detached from the community (Fig. 3).

Dominance curve was plotted for species of UWC against their rank abundance and log of sum values (Fig. 4). In the studied area the most dominant species was *Cynodon dactylon* and then following it were *Brachiaria ramose* and *Desmostachya bipinnata*. On the other hand the least abundant species in the area was *Buxus papillosa.*

Vegetation-soil interaction. CCA being a direct ordination technique plots the species response towards their specific edaphic factors. Variables such as pH, EC, OM, macronutrients (N, P and K) and micronutrients

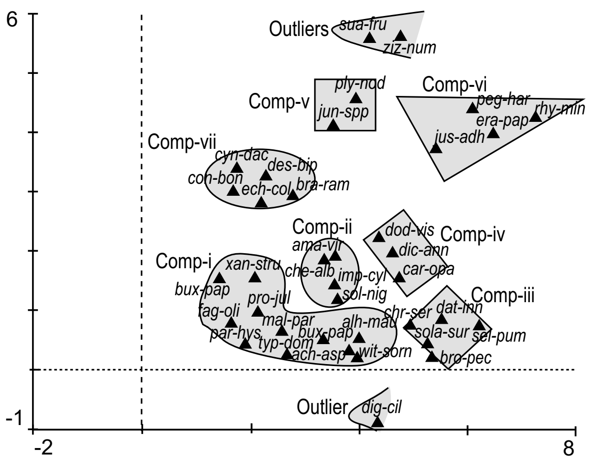

Fig. 2. Detrended correspondence analysis (DCA) with ucchali wetland complex (UWC).

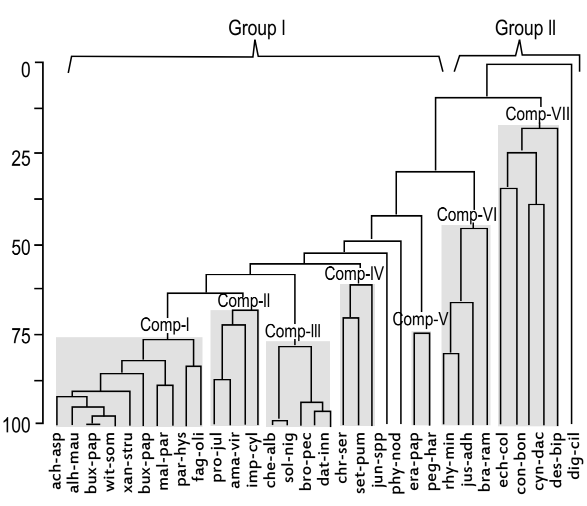

Fig. 3. Two way cluster analysis of UWC.

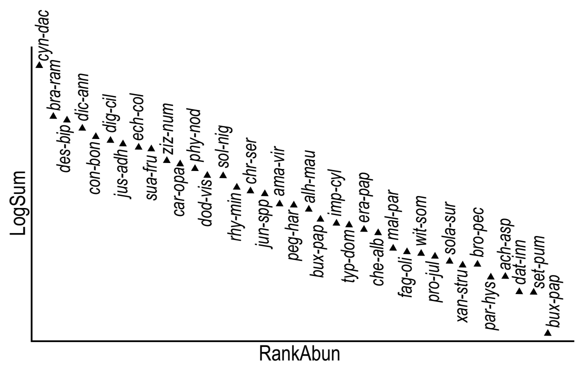

Fig. 4. Dominance curve for species of UWC

(Zn, Fe, Cu and Mn) were used to detect their promoting or limiting influence on growth of identified vegetation in the area.CCA biplot in Fig. 5 correlated the species against the edaphic factors of that particular region. The black triangles symbolize species, while red arrows correspond to the environmental variables. The angle that variables make with the line of axis illustrates its degree of correlation with that axis. The length of the arrow is proportional to its magnitude of influence on the species i.e., longer the arrow greater the influence and vice versa. Moreover, the species closer to the arrow signify its greater influence with that factor compared to the species that are plotted far away. Organic matter and elevation had the longest arrow than any other variable in the biplot hence it suggests its strongest effect on the species of UWC as compared to other edaphic factors. Phosphorus had more influenced on

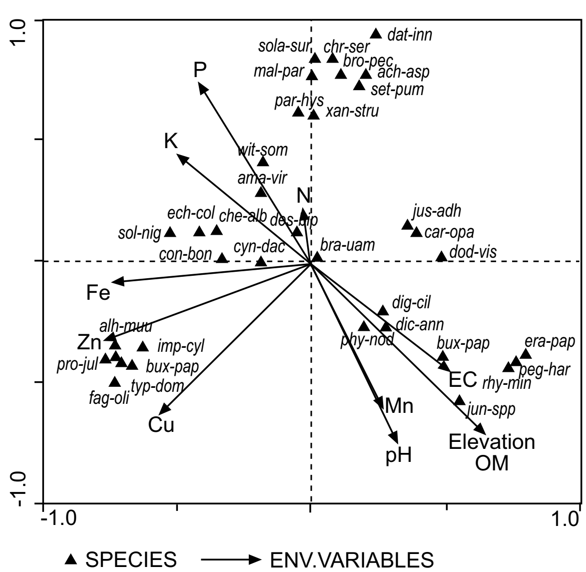

Fig. 5. Biplot UWC

the species: *Amaranthus viridis* and *Withania somnifera.* On the other hand *Dichanthium annulatum, Phyla nodiflora* and *Juncus* spp. were greatly influenced by organic matter in soil and elevation of the area. While EC affected on *Buxus papillosa* and *Digitaria ciliaris.* Similarly, Zn had shown major affect on the growth of *Alhagi maurorum, Prosopis julifora, Suaeda fruticosa, Imperata cylindrical, Buxus papillosa, Fagonia olivieri* and *Typha domingensis*. *Cynodon dactylon* the most abundant species in the UWC was remarkably affected by Fe in soil. N had the shortest arrow of all and seemed to impact *Brachiaria ramose* species. The species plotted far away were free of the impact of these plotted environmental variables whereas species in the close proximity responded well to its nearest variable.

Loess fitted model was used to draw data attribute plots of least and most abundant species of the area. This helped better to understand the specific species response with collective environmental variables. Each arrow of environmental variable shows its increasing value and angles between the arrows show the correlation between them. To assess this association with environmental variable *Cynodon dactylon* and *Buxus papillosa* was chosen since *Cynodon dactylon* was the most abundant species found in the area and *Buxus papillosa* was found to be less abundant comparatively to the other vegetation recorded in the UWC. In Fig. 6 *Cynodon dactylon* has uniform contour lines and no negative value which signifies its consistent distribution having positively influenced by the edaphic factors of the area. In contrast data attribute plot for *Buxus papillosa* in Fig. 7 illustrate its correlation with the environmental variables of the area. Fig. 7 depicts that this least abundant species have weak correlation as indicated by low values and random contour lines.

Pie symbol plots are used to represent environmental variables of the area quantitatively into fractions of classes based upon the number of samples. Each fraction of class is represented by separate colour code and has unique value range. The space between the pie symbols illustrates the relative abundance of species in sample plots. While the slices and their width represents the relative frequency and abundance of species in that class range.

Soil pH is a master variable that affects soil physical, chemical and biological properties. Degree of acidity or alkalinity affects which trees, shrubs or herbs will dominate the landscape under natural conditions and

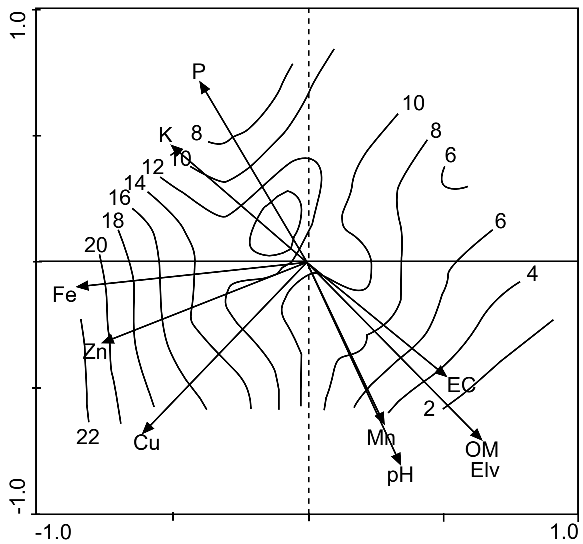

Fig. 6. Data attribute plot for *Cynodon dactylon* along with soil parameters

also controls which cultivated crops can grow well at that site (Brady, 1990). pH range of 5.5 to 6.5 provide the most satisfactory plant nutrients level overall (Brady and Weil, 1996) . The pH in the complex varied from 6.76 to 9.38 with the median value of 8.3 and had basic and alkaline properties due to prevailing dry arid climatic conditions. Most of the species favored the class pH-1 (i.e. 6.7-7.03) and this class range supported species

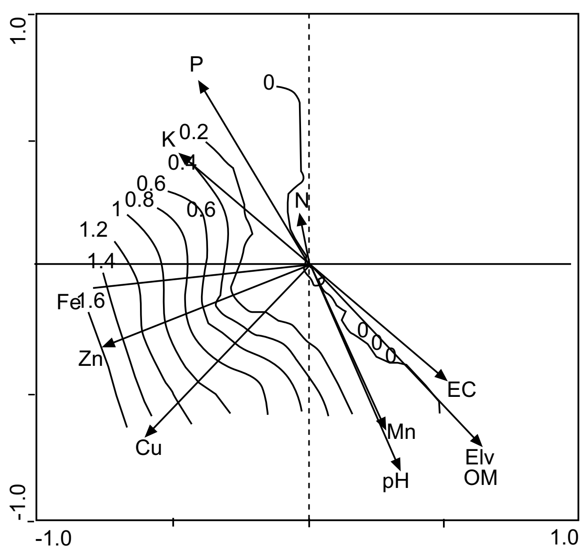

Fig. 7. Data attribute plot for *Buxus papillosa*along with soil parameters: Data attribute plot for *Buxus papillosa*along with soil parameters

diversity and richness. However certain species only grow in single pH range; for example *Solanum surattense, Datura innoxia* growth prevailed only in class pH-1 and *Buxus papillosa* only grew at pH-4 (Fig. 8a).

Soil EC measure amount of salts present in soil and is an indicator of soil health. The quantity of food provided to plant is controlled by soil EC (Kitchen *et al*., 1999). However, in arid and semi arid climates naturally excess salts are present (Zare *et al*., 2011). Soil of the region had EC value range of 7.43 to 9.85 dS/m. Species diversity is directly related with soluble salts in soil which correspond to soil electrical conductivity (Nakem *et al*., 2006). Four distinct classes for EC ranged from 7.43 to 9.85. These classes consisted of 38, 40, 35 and 37 number of species which illustrate the favourable EC range for species growth in the region to be EC-2 (Fig. 8b).

Organic matter (OM) is another important soil parameter that measures soil fertility. Organic matter by binding mineral particles holds and supply water and nutrients to plants. It defines growth, distribution, abundance and richness of species in an area (Rezaei, 2003). It has been reported that a well drained productive soil

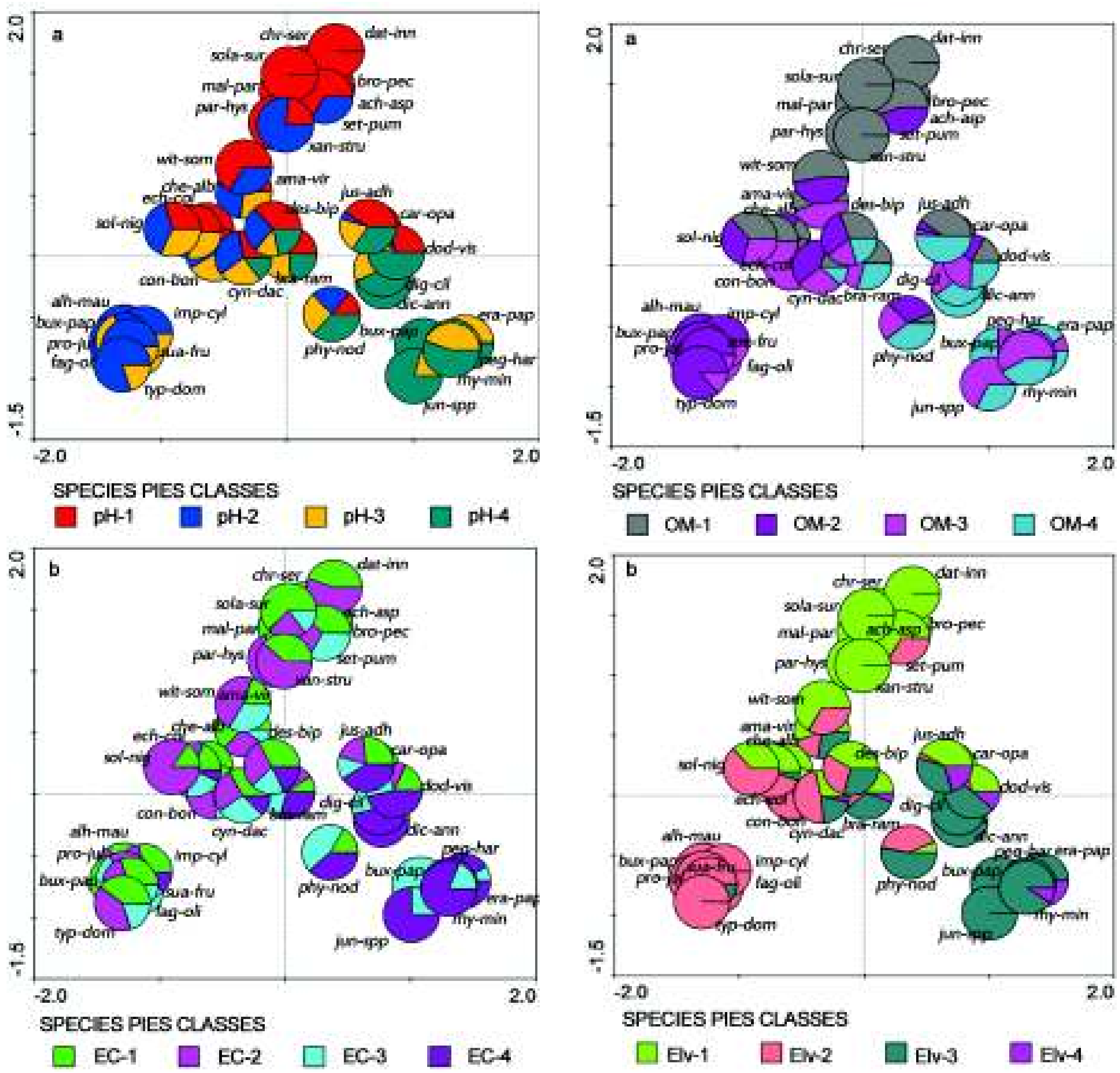

Fig. 8. Pie symbol scatter plot for (a) pH (b)EC (c) OM (d) elevation

constitute of 1 to 6% organic matter (Brady and Weil, 1996). The Fig. 8c explains the tolerance of species in terms of their survival to environmental gradient i.e., organic matter in the following case. This environmental gradient is classified into four distinctive classes. Soil in the vicinity of UWC had significant amount of organic matter ranging from minimum 0.57 to up to maximum 1.95%. The samples were distributed in these classes as 39, 37, 40 and 34. The OM-3 proved to be best class for species richness and its value range was 0.97-1.65. However, the *Xanthium strumarium, Solanum nigrum and Datura innoxia* could only persist in the range of OM-1.

Distinct altitudes have varying environmental conditions which ultimately lead to changing species distribution. Species such as (Fig. 8d) *Juncus* spp. and *Buxus papillosa* preferred higher elevation for its persistence compared to species *Xanthium strumarium*, *Datura innoxia* and *Chrysopogon serrulatus* which preferred lower elevations.

Nitrogen, phosphorus and potassium (N, P and K) deficiencies create complications in plants. Rowe *et al*. (2016) related the soil macronutrients availability with plants productivity in natural ecosystem. High concentration of macronutrients affects plant positively by increasing species abundance and distribution (Passioura, 2002). Most saline soils have low N and P content with high salt concentration and high species abundance (Ramakrishan and Kumar, 1976). Four classes were made on the basis of nitrogen in soil of selected quadrates. These classes had N value in ranges from 0.028-0.93 and had an average value of 0.04. Figure 9a showed that most of the species diversity could be found in N-1. The pie symbols in Fig. 9b represent species and these species were classified according to the available P in soil sample of the studied area. This was done to formulate the best range of class to favour the diverse number of species. The class values varied from 5.34 to 12.86 mg/kg with an average of 9.04. Class P-1 occupied 39 species, P-2 had 39, P-3 included 37 and P-4 contained 35 species. However, *Datura innoxia* showed growth only in P-4. While *Rhynchosia minima* only preferred P-1 class. Figure 9c represents the scatter plot for available K which divided into four ranges of classes. The range had maximum value of 95 to 377 mg/kg. These four classes contained 39, 41, 33, 37 species respectively. However, *Datura innoxia* favoured K-3.

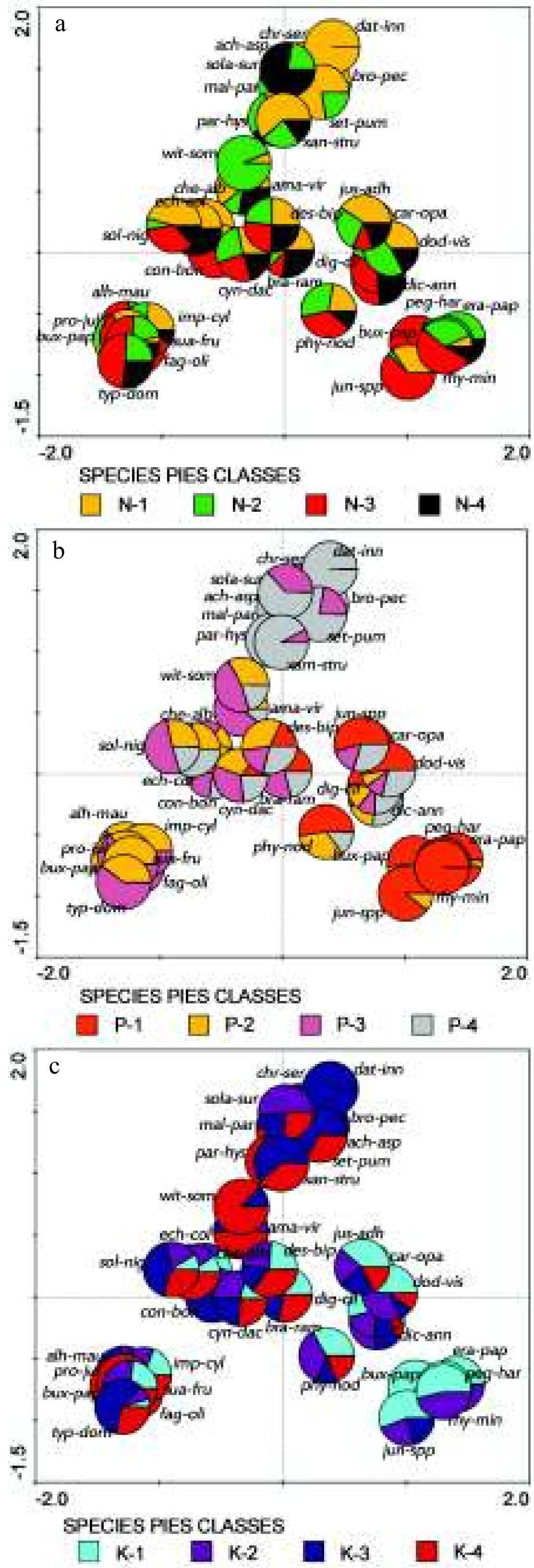

Fig 9. Pie symbol scatter plot for (a) K (b) N (c) P

The Zn value range of area could be divided into four distinctive classes. Each class represented a unique range; this was helpful in finding out the Zn range which favored species diversity. The value ranged from 0.1 to 0.99 with an average value of 0.44. However, some species preferred growth only in certain range of class. *Datura innoxia* cannot grow in any other class except for Zn-2 (Fig. 10a).

Graph in Fig. 10b had soil Cu value varying from 0.44-0.98 and had average of 0.73 with 63 distinct values. The calculated Cu of UWC could be divided into four distinct classes having separate Cu range to gather the best range that ensure diversity. It can be seen that some species only showed growth in a specific Cu range.

Having 63 distinct values the Fe calculated from the soil samples of the region had values starting from 1.02 to 4.9 with an average of 2.98. This range was classified to make four separate classes i.e. Fe-1, Fe-2, Fe-3 and Fe-4. Each class favoured specific species and number of species in these four classes were 38, 37, 39 and 36. However, Fig. 10c point up that there are few species that only grew in a particular Fe range. *Imperata cylindrical* showed growth only in Fe-1.

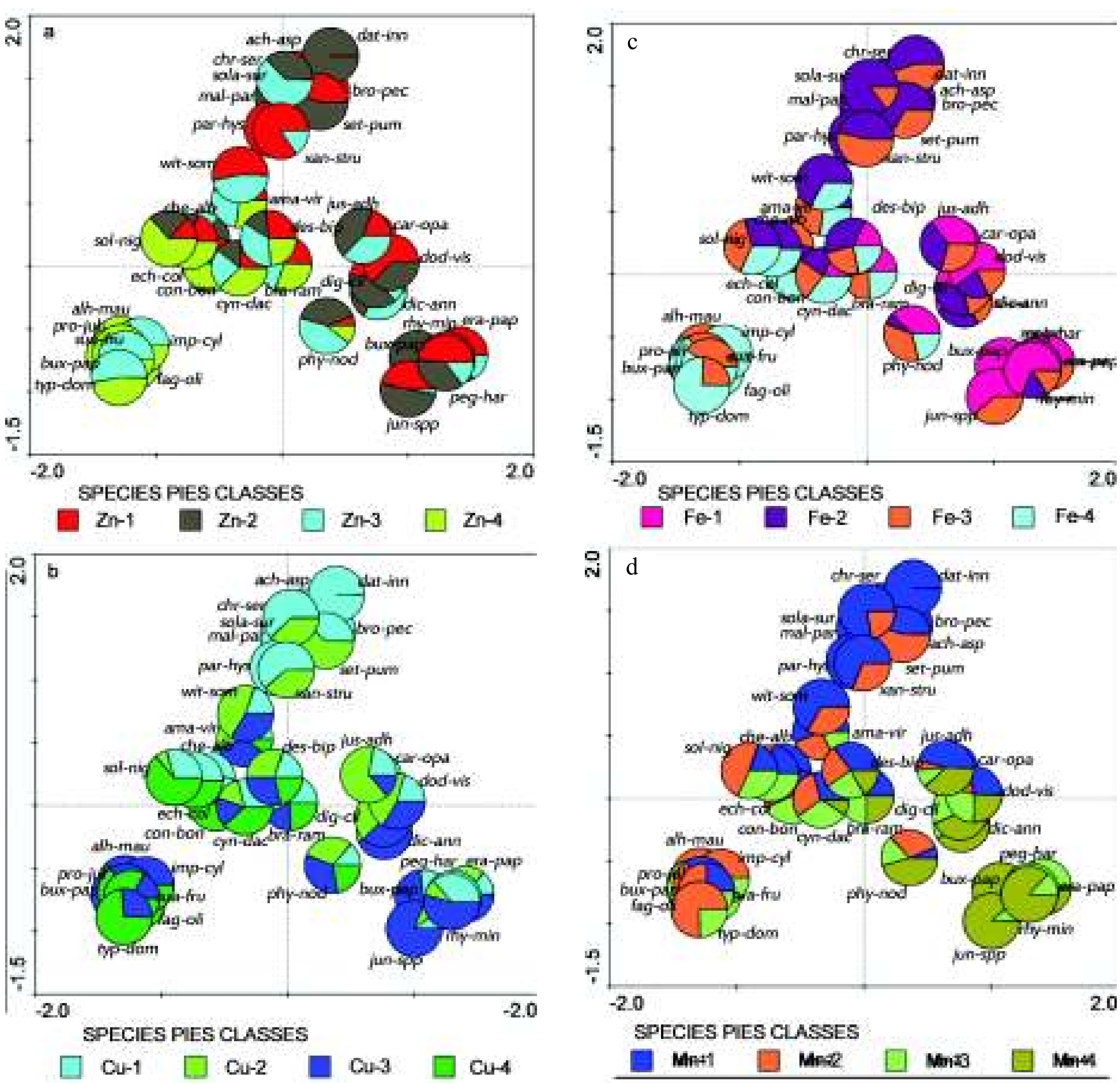

Fig 10. Pie symbol scatter plot for (a) Zn (b) Cu (c) Fe (d) Mn

Identified plant species Mn value ranged from 1.44 to 1.99. These classes had 43, 35, 37 and 35 members in them, respectively. Most of the species preferred to grow in first class i.e., Mn-1. Despite this *Rhynchosia minima, Juncus* spp*., Eragrostris papposa* and *Peganum harmala*only persisted in Mn-3 and Mn-4 i.e. Mn range of 1.71 to 1.99; as shown in Fig. 10d.

Despite all this, various non-native and invasive species were also recorded from the UWC. *Dodonea viscose* and *Prosopis* spp. found in the area are introduced species and grown as the result of overgrazing and land degradation (Arshad, 2011). *Dodonea viscose* is a small shrub of tropical, subtropical and warm temperate regions. It grows in open areas and is resistant to salinity, pollution and drought conditions (Selvam, 2007). *Prosopis* spp. is now considered problematic and difficult to identify because of its freely hybridizing nature with other species of the region (Zachariades *et al*., 2011). These species grow because of induced change in an area and alter the range ecology. The unique ecosystem of the complex may further get deteriorated by these invasive species since they replace the indigenous flora and climax species of the region. The UWC has three Ramsar sites and supports wide variety of important migratory birds and globally threatened wildlife, and change in ecology may affect this biodiversity in the longer term. As a result existing habitat and the dependent wildlife cannot readily adapt to the changing conditions and ultimately results in dispersal of local species from the area.

Conclusion

This study successfully provides an ecological interpretation of distribution of plant species and their communities along the edaphic factors in UWC. The vegetation composition of the area is defined by arid climatic conditions, high soil moisture and low nitrogen content. Elevation, organic matter and pH were more significantly correlated and were identified as major factors driving the floristic patterns. However, is continuous conservation of species diversity is required and medicinal flora must be valued in the area for effective management. GIS based census study of flora and fauna must be done in order to recognize and identify the important wildlife corridors in the vicinity of the complex, so as to prioritize the area in terms of its protection, promotion and maintenance of ecological processes.

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