Soil & Environ. 28(2): 106-112, 2009
www.se.org.pk
ISSN: 2074-9546 (Print)
ISSN: 2075-1141 (Online)

Multivariate analysis of environmental and vegetation data of Ayub National Park Rawalpindi

T. Jabeen and S.S. Ahmad*
Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi, Pakistan

Abstract

National Parks are designated to protect the ecological integrity of one or more ecosystems for present and future generations. Pakistan has more than 20 national parks. The aim of this research was to quantify the vegetation in Ayub National Park using ordination techniques. The research was conducted to determine the soil-vegetation relationship and quantify the floristic composition of National Park vegetation data of Ayub National Park. The data was recorded using quadrat method. A strategy of simple random sampling was used for naturally grown plants (herbs and shrubs). Thirty quadrats were tossed randomly at different locations and spies were identified. In all 44 plant species were identified. The soil of each quadrate was taken as environmental variable for electrical conductivity, pH and heavy metals detection. Classification and ordination were carried out using PC-Ord version 5 CANOCO 4.5. Vegetation profile of study area resulted in ten most abundant species present in Ayub National Park having cover value of >15%. Classification of vegetation data with TWINSPAN resulted in species dichotomy, represented by two major communities. Deterended Correspondence Analysis (DCA), results indicated the presence of four major plant communities, while Canonical Correspondence Analysis (CCA), results confirmed the species correlation and association with soil with the help of soil EC, pH, and with heavy metals detection.

Key words: Ayubia National Park, Soil-vegetation relationship, multivariate analysis

Introduction

The International Commission on National Parks has precisely defined a National Park with respect to its status i.e. they will be used for protection and conservation of ecosystems, together with scientific research, education and recreation. The early ideas on the nature of National Parks derive from the U.S.A. where the first park was created in 1872. After then in Canada, Australia and New Zealand as well as in U.S.A , the protection of 'monumental scenery' and 'wilderness' from the damage caused by the exploitation of mineral and forest resources was clearly associated with a determination to develop tourism (Pullan, 1988). The recognized primary use of the parks has been outdoor recreation and, more recently, the conservation of representative examples of natural ecosystem (Rivard *et al*., 2000). Thus, National Parks can be regarded as the most significant ecological reserves. The National Park of Pakistan is an outstanding area due to its merit and natural beauty where the landscape, flora and fauna are sheltered, preserved in a natural state and provides access for recreation, education and research to the public. Access roads and other facilities should be planned in such a way that they do not conflict with the main objectives of the national parks. Hunting wild animals is prohibited, as is firing gun or otherwise interfering with animals and plants. Clearing land for cultivation, mining or allowing polluted water to flow into the national parks is also prohibited. There are 20 National Parks in Pakistan and AJK out of which 14 covering a total area of 2.8 million ha. The average size of protected areas is 0.20 million ha. The National Park's consent that species richness should not be lower than naturally occurring and changes in composition resulting from human actions should be as low as possible. However conservation goals, such as the protection of particular endangered species, must be applied to individual parks (Rivard *et al*., 2000). Vegetation is known to significantly influence the chemistry of soils, while soils affect the physiognomy, composition, and productivity of plant communities (Klinger, 1996). To study the vegetation–environment relationships, Hejcmanova-Nezerkova and Hejcman (2006) conducted a study. They used CCA to evaluate the effect of soil type, topography and termitaria presence on the vegetation structure and found that soil type and topography are the main factors affecting woody vegetation of the locality.

Multivariate data commonly used in a variety of disciplines; is easy to understand with the approaches and methods described in multivariate data reduction and discrimination. Rao (1964) developed the method for principal component analysis. Lebreton *et al*. (1988a and 1988b) proposed a new multivariate method that addressed directly the question of vegetation-environment

*Email: shsaeed1@yahoo.com

relationships. DCA is an indirect gradient analysis technique (Hill and Gauch, 1980) that detects gradients in species composition from species abundance data. Kazi *et al*. (2008) applied multivariate statistical techniques e.g. Cluster Analysis (CA) and Principal Component Analysis (PCA) to the data on water quality of Manchar Lake (Pakistan), generated during 2005–06, with monitoring at five different sites for 36 parameters. The results revealed that the major causes of water quality deterioration were related to inflow of effluent from industrial, domestic, agricultural and saline seeps into the lake and also resulting from people living in boats and fishing.

This significance of the current study lies in the fact that outcome of this work would be useful in highlighting prerciling status of rejection in Ayub National Park. Moreover, we aimed to create awareness for those areas that are protected and their natural vegetation need to be preserved for recreational and educational purpose. In this context, we followed ordination technique in order to quantify the soil-vegetation relationship based on multivariate analysis.

Present study was conducted to create awareness to protected natural and scenic areas of National or International significance for scientific, educational and recreational use and preservation of nationally significant natural features. The objective of our research was to quantify the vegetation in Ayub National Park using ordination techniques. To study the soil vegetation relationship using multivariate analysis.

Materials and Methods

Vegetation data of Ayub National Park were taken by Quadrat method. Within each quadrat, vascular plants and their estimated cover values were recorded using visual estimation by the Domin cover scale (Kent and Coker, 1995). Sampling was done during the months of April to late June 2008. A strategy of simple random sampling was used. Plant species were identified using flora of West Pakistan by Stewart (1972).

Soil environmental parameters pH, Temperature and EC were recorded from each of thirty 1 x 2 m^2. pH of soil was determined by using glass electrode pH meter, Thermo Orion (Model 410 A +)

EC as mS cm^{-1} was measured using EC meter probe (Conductivity-^{o}C meter, Cyberscan 500 con). Soil samples were analyzed for heavy metals Cu, Cd, Ni, Zn, Pb, and Cr. The method used for detection was acid digestion method following the procedure of hotplate aqua regia (Eaton, 1995) and using Atomic Absorption Spectrophotometer. Multivariate analysis was carried out using PCOrd 5 and CANOCO 4.5.

Results

The results of the study are divided into three sections. Section one describes the over all vegetation pattern and grouping of different plant communities by TWINSPAN and DECORANA. Second section describes the over all plant species assemblages or data diminution recorded and detailed results of their analysis. Last section i.e. section three elaborates the relationship between various plant species and communities established with the various environmental factors using Canonical Correspondence Analysis (CCA).

On the basis of vegetation of the study area, which comprised of floristic data collected from 30 quadrats, 44 vascular plants species belonging to 32 families were recorded; out of 44 species only 16 species occurred with a frequency of more than 15 percent (Figure 1). Two-way indicator species analysis (TWINSPAN)) was applied to the floristic data to obtain a first approximation of the plant communities of the area. Large groups suggested by TWINSPAN were further sorted by running individual TWINSPAN procedures for those groups. These results clearly indicated that at the first level TWINSPAN divided the vegetation of whole study area into two major communities, which were further divided into sub-communities and sub-minor communities.

Vegetation of the study area was classified further using DCA (Detrended Correspondence Analysis) technique. Vegetation of the Ayub National Park was sampled at different locations. From the Ordination (DCA) methods following major plant species groups were identified based on Figure (2). Based on the cluster analysis vegetation types were resulted in a dendogram.

Group I: *Polypogon monspeliensis* and *Asparagus officinalis* group.
Group II: *Cenchrus ciliaris* and *Euphorbia helioscopia* group.
Group III: *Dodonaea viscosa* and *Parthenium hysterophorus* group.
Group IV: *Otostegia limbata* and *Broussonetia papyrifera* group.

Group 1. Polypogon monspeliensis and Asparagus officinalis community

The species in this group include *Polypogon monspeliensis, Taraxacum officinale, Avena sativa, Asparagus officinalis* and *Triticum aestivum.* This group was named as *Polypogon monspeliensis* and *Asparagus* *officinalis* representing dominant species of the community, having highest cover values in this low size class. This group was grown along the canal. Canal was rather dirty and polluted. The area was of open type, where tree species were cleared and were spaced for track. Soil was having neutral pH and was rather fertile. Within this habitat only five species were recorded. Diagnostic species of this group were *Polypogon monspeliensis* (Poaceae/Gramineae) and *Asparagus officinalis* (Liliaceae/Asparagaceae) with the cover values of 19% and 17% respectively. *Taraxacum officinale* and *Avena sativa* were co-dominant species while *Triticum aestivum* was an associated specie.

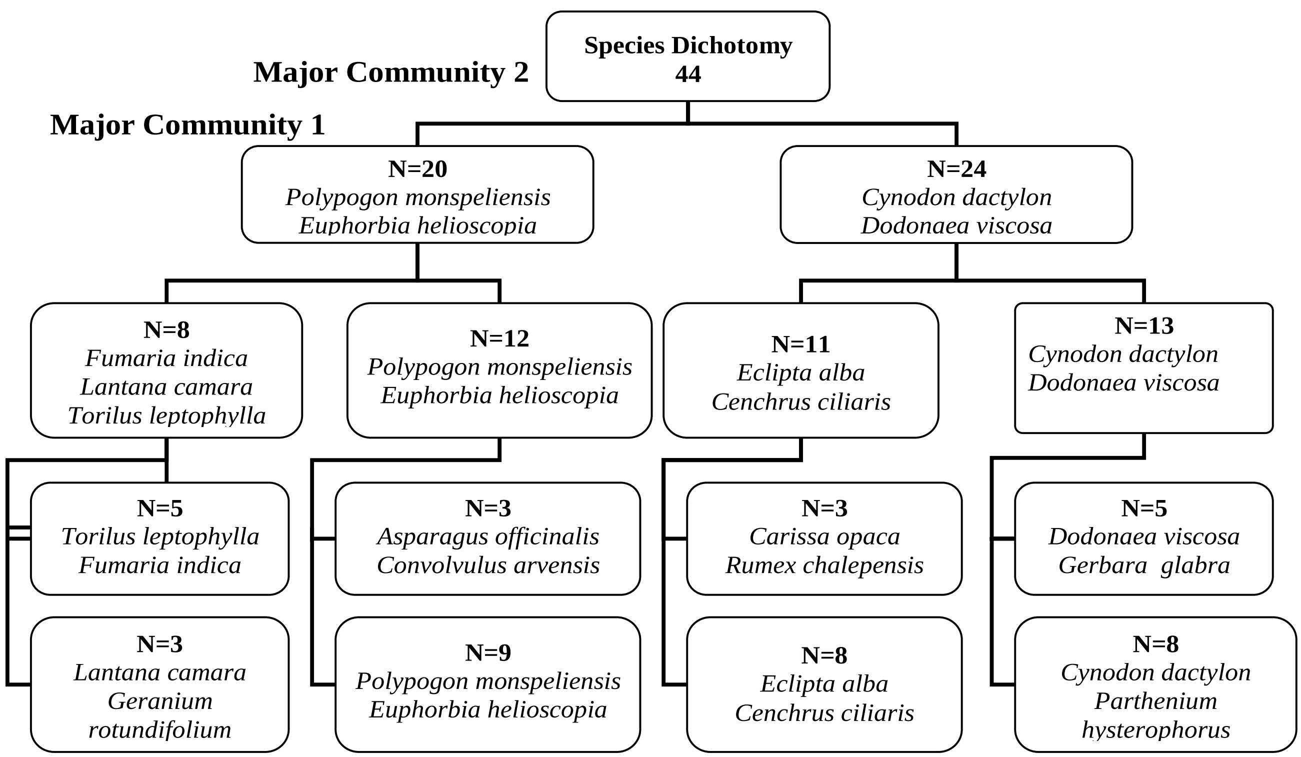

Figure 1. Species dichotomy demarcated by TWINSPAN

Group 2. *Cenchrus ciliaris* and *Euphorbia helioscopia* community

The species present in this group include *Rumex chalepensis, Malva neglecta, Cynodon dactylon, Vicia sativa, Phalaris minor, Euphorbia helioscopia, Fumaria indica, Geranium rotundifolium, Vicia faba, Eclipta alba, Torilus leptophylla, Sonchus asper, Convolvulus arvensis, Lantana camara, Geranium wallichii, Stellaria media, Eragrostis poides* and *Cenchrus ciliaris.* This group was named as *Cenchrus ciliaris* and *Euphorbia helioscopia* group due to the highest cover values of the two species within the group. This community was found at the top of mountain as well as on the slope. The hilly area soil was light brown in color as well as hard in texture while slopy soil was moist. Trampling was rare due to the slopness of the hill. This community is attaining the highest number of species in DCA classification. Dominant species showed a good regeneration pattern. The herbaceous stratum was relatively well developed with a canopy cover of 40%. *Cenchrus ciliaris,* and *Euphorbia helioscopia* were diagnostic species with cover values of 40% to 28% respectively. The co-dominant species of the group were *Cynodon dactylon* of family Poaceae with the cover value of 27%. *Rumex chalepensis, Malva neglecta, Vicia sativa, Phalaris minor, Fumaria indica, Geranium rotundifolium, Vicia faba, Eclipta alba, Torilus leptophylla, Lantana camara* and *Stellaria media* were associated species while three species were recorded as rare.

Group 3. *Dodonaea viscosa* and *Parthenium hysterophorus* community

Parthenium hysterophorus, Nasturtium officinalis, Gerbara glabra, Asparagus gracilis, Calendula arvensis, Duchesnea indica and *Dodonaea viscosa* were the species included in this community. This group was designated as

Dodonaea viscosa and *Parthenium hysterophorus* group due to highest cover values of these two species in the group. This community developed in the zoo and area behind it. The vegetation of this area was dense in the back yard of the cages. The community might be regarded as trampled because of intense human disturbance. It established easier on the surroundings of the Ayub National Park. Though this community occurred only in nine quadrats, but the exclusive species exhibits a fairly good cover values. *Dodonaea viscosa* and *Parthenium hysterophorus* were the diagnostic species of the community with cover values of 27% and 26% respectively. Sampling plots showed *Duchesnea indica*, *Nasturtium officinalis* and *Asparagus gracilis* as co-dominant species in the group. While the remaining species act as associated species.

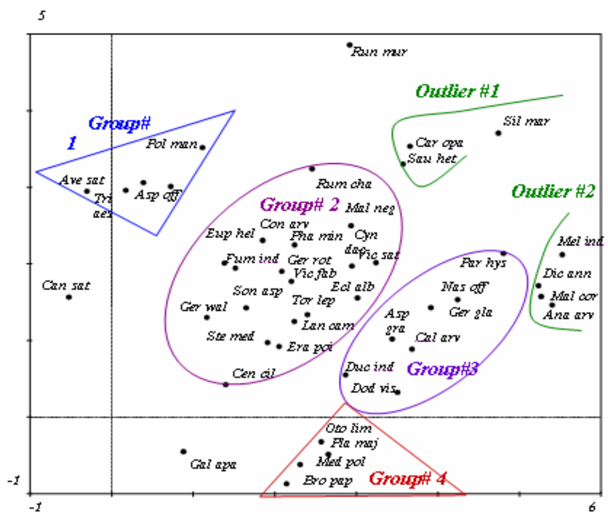

Figure 2. Groups demarcated by Detrended Correspondence Analysis

Group 4. Otostegia limbata and Broussonetia papyrifera community

The species present in this group were *Otostegia limbata*, *Plantago major*, *Medicago polymorpha* and *Broussonetia papyrifera*. This group was designated as *Otostegia limbata* and *Broussonetia papyrifera* group due to highest cover values of these two species in the group. This community developed on the shoulder of the road, close to the asphalt surfaces on heavily compacted man-made soils which have a high percentage of gravel in the soil surface, and can be regarded as a trampled community. This trampled community was situated along the entire area of the road of Ayub National Park. Human disturbances (overgrazing, cutting for timber, lopping) and deforestation have been frequently reported by various workers in this region. *Otostegia limbata* and *Broussonetia papyrifera* were diagnostic species with cover values of 24% and 20% respectively.

To ascertain overall patterns of plant species distribution based on environmental variables, CCA ordination was performed on a medium containing %age cover value for all species (n = 44 species) in 30 quadrats (Figure 3). Similarly, CCA was also performed on pavement vegetation along the environmental variables, parameters selected for CANOCO analysis, pH, electrical conductivity and temperature.

In the biplot, the points represent individual species and an arrow to each environmental variable. The points plotted to the direction of maximum change of the environmental variable across the diagram. Across the diagram, the length of arrow was proportional to the magnitude of change in that direction of maximum change of environmental variable. Long arrow was more closely correlated in ordination than those with short arrow and is much more important in influencing the community variation. Species with their perpendicular vegetation near to or beyond the tip of arrows will be strongly correlated and influenced by the arrow. Those at opposite end will be less strongly affected (Figure 2).

Overall species were grouped in the center of the diagram and no environmental factor seems to be influencing or correlating the groupings of the species. However, length of arrow of electrical Conductivity and pH play some significant role in the grouping of few species. Electrical Conductivity was more towards the large arrow and showed the strong correlation of *Asparagus gracilis* (Liliaceae/Asparagaceae), *Triticum aestivum* (Poaceae), *Asparagus officinalis* (Liliaceae/Asparagaceae), and *Avena sativa* (Poaceae). The pH arrow indicating that *Geranium rotundifolium* (Geraniaceae), *Rumex chalepensis* (Polygonaceae) had strong correlation while, *Fumaria indica* (Fumariaceae) was portraying some significant correlation as well. Most of the species were scattered sparsely and environmental variables seemed to play non-significant role in grouping of species or species showed no definite association.

In figure (4) copper and zinc portray strong correlation with respect to distribution of various species towards the axis-1. Copper showed more role in grouping of *Plantago major* and *Eragrostis poides*. Nickel showed more association towards the *Medicago polymorpha*. Zinc was showing significant correlation towards axis-2 and those species showing strong correlation were *Saussurea heteromalla* and *Carissa opaca*. Lead, Cadmium and Chromium showing relatively week correlation. Most of the species were lying on the outliers of environmental variables.

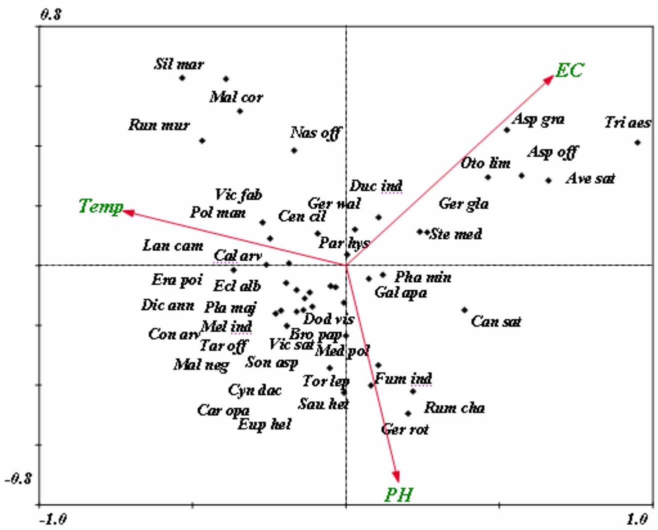

Figure 3. Biplot of species and environmental variables showing the CCA

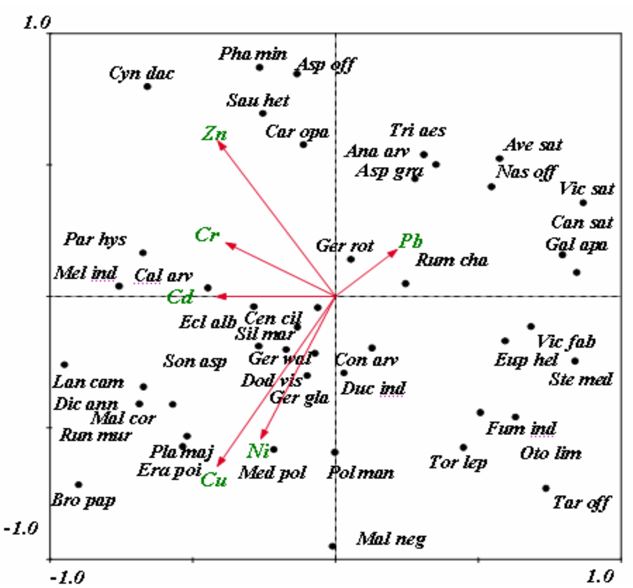

Figure 4. Biplot of species and heavy metals in the study area

Discussion

The present study examined the species distribution in different areas of Ayub National Park, Rawalpindi. A total of 44 herbaceous plant species were recorded from the different locations of the Park. The presence of a diverse range of herbaceous plant species in the area supports the view that the Park can serve as an important habitat for preservation of the local flora. One of the most important components controlling vegetation cover is the soil, and both vegetation and soil are influenced by topography amongst other things (Solon *et al*., 2007).

Table (1) enumerated the ten most abundant species having cover value>15% in the study area. *Cenchrus ciliaris, Cannabis sativa, Euphorbia helioscopia, Dodonaea viscosa, Cynodon dactylon, Ranunculus muricatus, Parthenium hysterophorus, Carissa opaca, Otostegia limbata* and *Saussurea heteromalla* were the most abundant species in the study area. In the same way He *et al.* (2006) collected seventy species representing 46 genera and 16 families in China. In their study the largest families were Leguminosae, Polygonaceae, Gramineae and Compositae, representing 20.0%, 15.7%, 14.3% and 14.3% of the total flora, respectively. Ahmad *et al.* (2004) and Ahmad (2007) carried out same study for roadside verges of M-2 and along Havalian, Pakistan.

Table 1. Most abundantly occurring species of study area (In order of decreasing percentage cover in 30 quadrats)

Specie name	Cover value %
Cenchrus ciliaris	40
Cannabi sativa	28
Euphorbia helioscopia	28
Dodonaea viscosa	26
Cynodon dactylon	26
Ranunculus muricatus	26
Parthenium hysterophorus	26
Carissa opaca	25
Otostegia limbata	23
Saussurea heteromalla	20
Broussonetia papyrifera	20
Rumex chalepensis	19
Polypogon monspeliensis	19
Nasturtium officinalis	17
Asparagus officinalis	16
Anagallis arvensis	16

In order to understand vegetation-soil correlation, multivariate techniques like TWINSPAN, DCA, and CCA were applied. TWINSPAN was used, which divided the vegetation into two major communities *Polypogon monspeliensis* and *Euphorbia helioscopia*, for community 1 and *Cynodon dactylon* and *Dodonaea viscosa for community-2*. *Cynodon dactylon* and *Cenchrus ciliaris* were present in the same group and were found almost every quadrat at different frequencies. Dominance of the species like *Cynodon dactylon* in the study area was supported by the fact that it was regarded as distinctive species for trampled habitat (Cillers and Bredenkamp, 1999). *Cynodon dactylon* and *Cenchrus ciliaris* (African foxtail), prefer a highly disturbed and poor habitat. The dominance of *Cynodon dactylon* was supported by the fact that this perennial grass is quite aggressive in nature and grows quickly and completes its life cycle in four months. Due to this aggressive charachteristics, Cynode-dactylon was found higher density (cover value > 26). Similarly perennial rhizomatic *Cenchrus ciliaris* forms a mat and increases its cover area. That is why both species were found in the same group (Ahmad *et al.*, 2004).

DCA results divided the vegetation of the study area into four major communities also named as groups. The vegetation groups from DCA were *Polypogon monspeliensis* and *Asparagus officinalis* (group1), *Cenchrus ciliaris* and *Euphorbia helioscopia (*group2). *Dodonaea viscosa* and *Parthenium hysterophorus* (group3) *Otostegia limbata* and *Broussonetia papyrifera* (group 4). The groups of DCA showed the species abundance with respect to the human activity. Naqinezhad *et al*. (2008) conducted study and five vegetation groups were confirmed by Detrended Correspondence Analysis (DCA) and were interpreted with major environmental gradients.

For vegetation-soil correlation, another multivariate technique CCA was applied. Electrical conductivity and pH had played some significant role in the grouping of few species. The Electrical conductivity showed the strong association of *Asparagus gracilis*, *Triticum aestivum*, *Asparagus officinalis* and *Avena sativa*. The pH indicated that *Geranium rotundifolium* and *Rumex chalepensis* had strong correlation irrespective of the *Fumaria indica*. It was interesting to observe in the field that those species which were mostly grouped around EC and pH biplot were also grouped together; *Asparagus gracilis* and *Triticum aestivum* were grown mostly in the same quadrat as well as *Geranium rotundifolium* and *Rumex chalepensis*. Similarly CCA results of Jiang *et al*. (2007) showed that the change in vegetation types along the altitudinal gradient was much greater than that along the north-south latitudinal gradient, though the contribution of the location factors to the distribution in vegetation types was apparent. The sensitivity of vegetation type along altitude gradient is proven by many studies. Moreover the structure and composition of prevailing vegetation type is more adapted to climatic conditions which are better reflected along altitudinal gradients.

Heavy metals played a significant role in the vegetation grouping of Ayub National Park. Three heavy metals i.e. Pb, Cr, and Cd showed no correlation, whereas Copper and Zinc portrayed strong correlation. Copper influenced more grouping of *Plantago major* and *Eragrostis poides*. However Zn was showing significant correlation towards *Saussurea heteromalla* and *Carissa opaca*. Similar study was conducted by Tembo *et al.* (2006) in Kabwe mine for the spatial distribution of four heavy metals in soils.

The results highlighted the need for further research, in order to determine the permitted levels of metals in soil samples as well as to identify areas of potential toxicity.

References

Ahmad, S.S. T.Ahmad and K.F.Akbar .2004. Baseline study of roadside vegetation of Lahore-Islamabad motorway (M-2) and its fertility status. *Pakistan Journal of Biological Sciences*, 4(2): 266-270.

Ahmad, S.S .2007. Medicinal wild plant knowledge from Lahore-Islamabad motorway, (M-2).*Pakistan Journal of Botany* 39(2): 355-377.

Cillers, S.S. and G.J. Bredenkamp. 1999. Analysis of the spontaneous vegetation of intensively managed urban open spaces in the Potchefstroom Municipal Area, North West Province, South Africa. *South African Journal of Botany* 65, 59–68.

Eaton, A.D. 1995. Standard methods, 19th Edition, American Public Health Association, Washington. 3-53.

He, M.Z., J.G. Zheng, X.R. Li and Y.L. Qian. 2006. Environmental factors affecting vegetation composition in the Alxa Plateau, China. *Journal of Arid Environments* 69(3): 473-489.

Hejcmanova-Nezerkova, P. and M. Hejcman. 2006. A canonical correspondence analysis (CCA) of the vegetation–environment relationships in Sudanese savannah, Senegal. *South African Journal of Botany* 72(2): 256.

Hill, M.O. and G.H. Gauch. 1980. Detrended Correspondence Analysis, an improved ordination technique. *Vegetation* 42: 47-58.

Jiang, Y., K. Muyi, Z. Yuan and X. Guangcai. 2007. Plant biodiversity patterns on Helan Mountain, China. *Acta Oecologica* 32(2): 125-133.

Kazi, T.G., M.B. Arain, M.K. Jamali, N. Jalbani, H.I. Afridi, R.A. Sarfraz, J.A. Baig and A.Q. Shah. 2008. Assessment of water quality of polluted lake using multivariate statistical techniques: A case study. *Ecotoxicology and Environmental Safety*: In Press, Corrected Proof.

Kent, M. and P. Coker. 1995. *Vegetation description and analysis, 2nd ed*. John Wiley and Sons. Chichester.

Klinger, L.F. 1996. Coupling of Soils and Vegetation in Peatland Succession. *Arctic and Alpine Research* 28(3): 380.

Lebreton, J.D., D. Chessel, M. Richardot-Coulet and N. Yoccoz. 1988b. L'analyse des relations especes-milieu par I'analyse canonique des correspondances. II. Variables de milieu qualitatives. *Acta Oecol (Oecol Gen)* 9: 137-151.

Lebreton, J.D., D. Chessel, R. Prodon and N. Yoccoz. 1988a. L'analyse des relations especes-milieu par l'analyse canonique des correspondances. I. Variables de milieu quantitatives. *Acta Oecol (Oecol Gen)* 9: 53-67.

Naqinezhad, A., H. Behnam and A. Farideh. 2008. Vegetation–environment relationships in the alderwood communities of Caspian lowlands, N. Iran (toward an ecological classification), In Press, Corrected Proof.

Pullan, R.A. 1988. Conservation and the development of National Parks in the humid tropics of Africa. *Journal of Biogeography* 15(1): 174-180.

Rao, C.R. 1964. The use and interpretation of principal component analysis in applied research. *Sankhya A*26: 329-359.

Rivard, D.H., P. Jean, P. Daniel, C. Michel and D.J. Currie. 2000. Changing species richness and composition in Canadian National Parks. *Conservation Biology* 14(4): 1100.

Solon, J., D. Marek and R. Ewa. 2007. Vegetation response to a topographical-soil gradient. *CATENA* 71(2): 309-320.

Stewart, R.R. 1972. An annotated catalogue of the vascular plants of West Pakistan and Kashmir. In: Flora of Pakistan Agricultural Research Council, Islamabad. 1029.

Tembo, B.D., S. Kwenga and C. Joseph. 2006. Distribution of copper, lead, cadmium and zinc concentrations in soils around Kabwe town in Zambia. *Chemosphere* 63: 497–501.