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# SPATIAL PATTERNS OF VEGETATION WITH UNDERLYING SOIL PROPERTIES PREVAILING ALONG DRAIN SIDE AREAS IN ISLAMABAD CITY

**SYEDA MARIA ALI[1*] AND RIFFAT NASEEM MALIK[2]**

[1*]*Department of Environmental Science, Female Campus, International Islamic University, Islamabad, Pakistan*
[2]*Environmental Biology Lab, Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan*

**Abstract**

Present study was conducted in Islamabad one of the rapidly growing city of Pakistan the and aimed to identify vegetation communities prevailing along drain sides and their relationship to the underlying soil properties. A total of 186 quadrats were recorded which covered the whole stretch of drains passing throughout the city. A total of 18 edaphic properties were determined in acid extractable surface soils of each quadrat. Two way indicator species analysis (TWINSPAN) identified two major communities (*Broussonetia-Populus* and *Panicum-Conyzanthes* community types). Amongst weeds, species such as *Cynodon dactylon*, *Malvestrum coromendilianum* and *Parthenium hysterophorus* were more frequent. Detrended Correspondence Analysis (DCA) identified environmental gradients to vegetation distribution. First ordination axis demonstrated hierarchical vegetation gradient shift of species from trees to herbs due to transformation of land from open to constructed land whereas, second axis highlighted the influence of invasive species. The distribution pattern of vegetation influenced by soil physico-chemical properties was demonstrated by Canonical Correspondence Analysis (CCA) which explained a total of 11.25% variance. The results conclude that human disturbance has affected environmentally designed vegetation patterns. It is therefore necessary to take into account trends like human influence, land abandonment and land use for the maintenance and conservation of vegetation.

## Introduction

Knowledge and awareness of urban vegetation and urban environmental quality is important for natural resource conservation, improvement and management of urban ecosystem resources (Pysek, 1995). Vegetation environment relationships reveal different underlying processes that result in appearance of different vegetation patterns existing in urban ecosystems (Zeleny, 2008). Distribution of species richness is likely to be regulated by two or more environmental gradients (Pausas & Austin, 2001). Species richness of urban ecosystem is determined mainly by environmental conditions and the species pool (Leps, 2004) which is usually less considered by decision makers and planners due to little knowledge of advantages provided by natural vegetation. Environmental variables can be classified into direct, indirect and resource gradients (Austin & Smith, 1989). Direct variables include factors such as soil characteristics that have a direct effect on vegetation (Tayler, 2003). Area and geometry are amongst most important factors influencing species richness along topographic gradient (Sanders, 2002). Although altitude and topographical variables do not have any direct effect on the vegetation but their importance is based on their correlation with some direct or resource gradients. Resource variables include those factors which are consumed by the plants such as light or nutrients (eg., phosphorus and nitrogen etc.). In some instances, patch area and site age significantly relates with the species diversity (Hermy & Corneils, 2000). Other characteristics documented for specific urban sites associated with decreased tree growth rate are limited growing space (Rhoades

& Stipes, 1999) and nutrients imbalance (Dyer & Mader, 1986). Biotic factors also affect tree growth rate in urban ecosystems like competition with other plant species (Close *et al*., 1996; Rhoades & Stipes, 1999). Soil physical and chemical properties (texture, salt content, organic matter and pH) have a great influence on the occurrence of species in urban ecosystems (Fostad & Peterson, 1997).

Urban landscape structures in relation with vegetation communities have been meagerly studied, especially in Asian or Tropical countries (Alvey, 2006). Like most of the developing countries, Pakistan is facing environmental degradation due to rapid urbanization, industrialization and population growth (Qadir *et al*., 2008). In Pakistan, to our knowledge, no studies have been excited where prevailing distribution of urban vegetation is correlated with land use types. Unfortunately, there is not much awareness about this issue in the general public and policy makers. In recent years the appearance of Islamabad city has extensively been changed, as the land has been cleared for housing and developmental projects. Green spaces support the flora of both natural and man-made origin. Reserved green areas along drain sides present natural habitats while, man-made habitats are mostly represented along road-sides and in built up areas. This study therefore has been designed to identify different plant communities along drain side areas of Islamabad city i.e., flora including the degree of dominance by native and exotic species. Also it emphasizes on the assessment of the relative importance of soil and geographical variables in structuring plant species richness and diversity patterns.

## Materials and Methods

Islamabad city is located against the backdrop of Margallah Hills supporting natural terraces and meadows across the whole area. Mountain streams splash down from the Margallah Hills and the lush green ranges of the Murree Hills farther north, and join up with a profusion of small streams like Soan & Kurang tributaries of which pass across the whole city. Geographically it is situated at northern latitudes 33˚ 42' 0" and eastern longitudes 72˚ 10' 0" lying at an altitudes of 457 to 610 m above sea level (Fig. 1). Rawal Lake Reservoir constituting the catchment of Margallah Hills is situated in the south east of the city that serves as the largest water reservoir for the twin cities (Islamabad and Rawalpindi) and habitat for characteristic flora and fauna of the area (Islamabad Census Report, 1998). In the recent years dumping of sewage wastes and garbage material has pronounced effects on the flora and fauna of the major reservoir (Chen *et al*., 2005). Due to accelerated urbanization and developmental activities in the recent years, sewage wastes are being continuously discharged and dumped having adverse affect on soil environment (Chen *et al*., 2005).

This study focuses the floristic composition along drain side areas of the city. For the collection of vegetation abundance and environmental attributes along drain side areas of the city a quadrat size of 10m × 10m for trees and shrubs and 1m × 1m for herbs was used. Floristic species composition was calculated using percentage (%) cover (Kent & Coker, 1992). In total 186 quadrats were recorded. All plant species were recorded at the spot, while unidentified plant species were given a descriptive field name and brought to the herbarium of Quaid-i-Azam University. The nomenclature followed Nasir & Ali (1972).

Surface soils were collected from two to three random places within each quadrat from where species abundance data was recorded at a depth of 9 inches. It was made composite and placed in air tight polythene bags, labeled and brought to the Environmental Biology Laboratory, Quaid-i-Azam University, Islamabad. Before proceeding for further analysis soil samples were air-dried at room temperature and sieved through 2mm sized sieve to remove coarse particles, stones and debris.

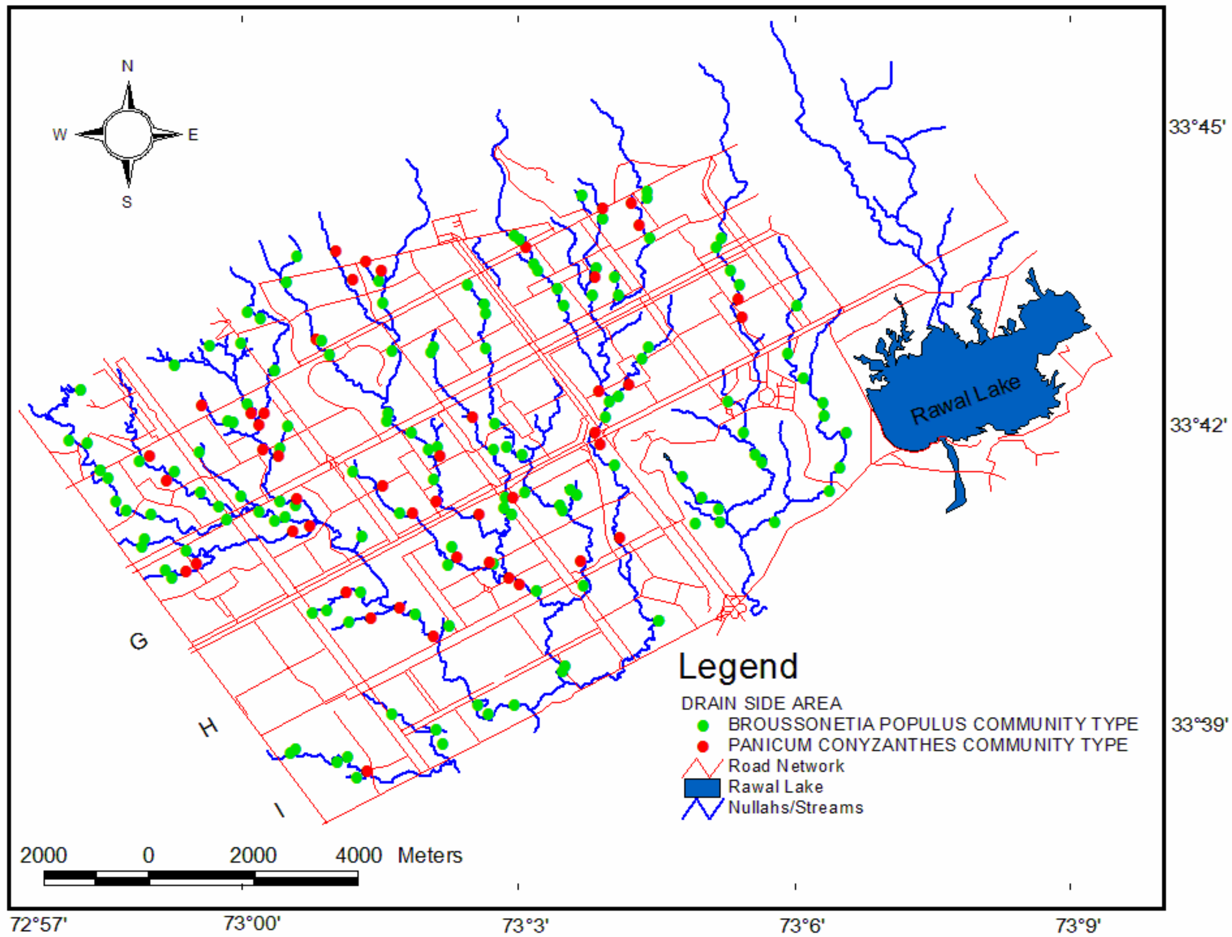


Fig 1. Location map of the study area showing distribution of Major Community Types along Drain side Areas.

The geographical coordinates of each quadrat were recorded with a Garmin (Geko 301) GPS. The topographic factors and anthropogenic disturbances were also noted during the field surveys.

Particle size i.e., sand, silt and clay and soil textural classes were determined by using the textural triangle (Robert & Frederick, 1995). Organic matter was determined by Tyurin's method (Nikolskii, 1963). The soil pH, EC and TDS were determined in soil solution in a ratio of 1:10, using a Milwaukee SM802 Smart combined meter with a glass electrode. $CO^{-}_{3}$ and $HCO^{-}_{3}$ were determined in soil saturation extracts by titration with dilute acid (Richards, 1969; Method No. 12). $Cl^{-}$ contents were determined by titration (Richards, 1969; Method No. 13). $NO_3^{-}$ were estimated by using nitrate test strips (Merckoquant® 1.10020). Soil acid digests were prepared using CEM (630W) closed vessel microwave digestion system for the determination of elemental concentration (Anon., 1998; Method 3051A). Metal concentrations of the major elements (Ca, Mg, Na, K and Fe) and trace metals (Cd, Co, Cu, Ni, Pb and Zn) in the solutions were measured using atomic absorption spectrometer (Varian FSS-240).

In order to identify vegetation communities in drain side areas Two Way Indicator Species Analysis (TWINSPAN) was performed (Hill, 1979a). To minimize noise in the floristic species composition data set only those species that were recorded in >3 quadrats were included in the analysis (Gauch, 1982). For TWINSPAN classification, species abundance x quadrat matrices was 113 x 186. The vegetation types identified were named after the first and occasionally the second dominant species.

The distinctness of the TWINSPAN vegetation classes were also evaluated using Detrended Correspondence Analysis (DCA) based on preliminary correspondence analysis (Jongman et al., 1995) and to detect the underlying environmental gradient and its association with plant communities distribution. The data matrices of species abundance (percent cover) versus quadrat for drain side areas (113 x 186) was subjected to DCA (Hill, 1979b). Rare species were down-weighted while axes were rescaled which may strongly influence multivariate analysis and obscure vegetation patterns (McCune & Mefford, 1999). DCA is an indirect ordination technique that provides a description of changes in the vegetation along with the environmental variables. DCA identifies linear combination of explanatory variables which explains a large part of the variation in the species data and strongly influence the spatial distribution of species.

Canonical Correspondence Analysis (CCA) was calculated (Ter Braak & Gremmen, 1987) to quantify floristic compositional responses to the explanatory environmental variables viz., soil physico-chemical properties and geographical coordinates. The first three constrained axes were tested statistically by Monte Carlo permutation tests. Three separate CCAs were performed independently with different sets of associated variables. First, the floristic data was analyzed in conjunction with the physical properties of soil (Sand, Silt and Clay) and geographical coordinates (latitude and longitude). Secondly, it was analyzed with the soil chemical properties (pH, EC, TDS, OM, $HCO_3^-$, Cl-, $NO_3^-$, $SO_4^-$, Ca, Mg, Na, K and Fe) and thirdly with the heavy metals (Cd, Co, Cu, Ni, Pb, Zn) contents in the top soils of the Islamabad city. The significant environmental variables were used in CCA along with the floristic matrix.

All classification and ordination analyses were performed using the software PCORD ver 4.16 (McCune & Mefford, 1999).

## Results

**Interpretation of classification groups:** The TWINSPAN analysis produced two major interpretable vegetation groups. The classification and functional features of the species groups are presented in Table 1. Plant communities showed preferences for relatively high soil moisture. The total number of species recorded in drain side areas was 113.

Vegetation growing along drain side across the city consisted of 113 species found in 186 quadrats which were presented by 98 genera belonging to 48 families. Fig. 1 shows the distribution of major plant communities along drain side areas. Euphorbiaceae, Fabaceae, Moraceae, Oleaceae and Poaceae. *Broussonetia*, *Dalbergia*, *Eucalyptus*, *Populus* and *Zizyphus* were the most dominant genera. In shrub and field layers herbaceous species such as *Cannabis sativa*, *Cynodon dactylon*, *Lantana camara*, *Panicum officinale*, *Parthenium hysterophorus*, *Malvestrum coromandelianum* and *Rumex dentatus* were recorded with higher densities.

At level 1 of TWINSPAN division, two major community types were identified (Fig. 2). First community type was represented mainly by invasive species such as *Broussonetia papyrifera*, *Populus euphratica*, *Parthenium hysterophorus* and *Cannabis sativa*, while the second group along drain sides was represented by the herbaceous flora dominated by *Panicum officinale*, *Conyzanthes graminifolius* and *Malvestrum coromandelianum* characteristic floristic composition of both community types is given in Table 1.

**Table 1. Functional features of major vegetation groups identified through TWINSPAN Classification.**

| Vegetation groups | Sub groups | 1st Dominant species | 2nd Dominant species | Habitat | Functional features |
|---|---|---|---|---|---|
| Group I (n=139) | i. (n=66) | *Broussonetia papyrifera* | *Populus euphratica* *Lantana camara* | Natural areas along drain sides | City area occupied by original native vegetation also influenced by the effect of invasive species |
| | ii. (n=73) | *Dalbergia sissoo* | *Cynodon dactylon* | Open green spaces both maintained and abandoned | Tree composition of exotic plants effecting not only natural vegetation but also human health |
| Group II (n=47) | i. (n = 47) | *Panicum officinale* | *Conyzanthes graminifolius* *Malvestrum coromandelianum* | Natural areas and abandoned land | Herbaceous flora emerging naturally and occupying most of the open spaces along drain sides |

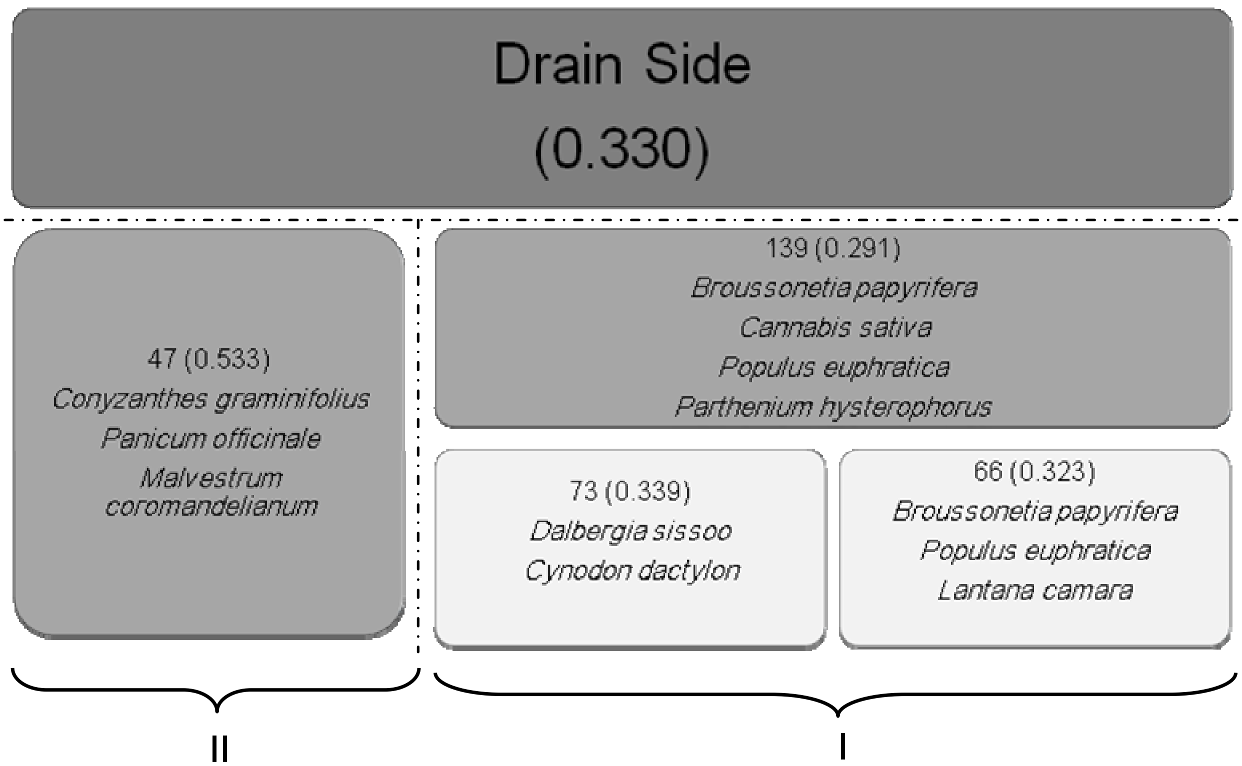


Fig. 2. Dendrogram of drain side areas generated through TWINSPAN classification technique. (*Levels are represented by different colors).

First community type was named as *Broussonetia-Populus* Community Type comprised of 139 quadrats. This community type could further be subdivided into two sub-community types; Sub-community type I was dominated by *Broussonetia papyrifera* and *Populus euphratica* associated with *Lantana camara*, an invasive intruder. Sub community type II was dominated by *Dalbergia sissoo* and comprised of 73 quadrats with an understory vegetation of *Cynodon dactylon*. Other frequently occurring species in this community type were *Alstonia scholaris*, *Cannabis sativa*, *Dichanthium annulatum*, *Ricinus communis*, *Rumex chalapensis*, *Rumex dentatus* and *Xanthium strumarium*.

Second community type was named as *Panicum-Conyzanthes* Community Type comprised of 47 quadrats representing sites recorded along drain side areas (Fig. 1). This community type also showed the association with *Malvestrum coromandelianum*. Other frequently occurring herb species in this community type were *Bidens bipinnata, Coronopus didymus, Crotolaria medicagiana, Dichanthium annulatum, Panicum officinale, Parthenium hysterophorus, Rumex dentatus and Zizyphus mauritiana.*

**Ordination using detrended correspondence analysis:** The eigenvalues for DCA axes 1, 2 and 3 of drain side were 0.60, 0.45 and 0.34 respectively. Urban vegetation is composed of combination of original natural and exotic vegetation. Along the right side of Axis 1 drain side vegetation prevails dominated by *Broussonetia papyrifera* and *Populus euphratica* Community Type whereas, along left side of ordination plot understory herbaceous vegetation dominates representative of drain side areas of densely populated areas of the city (Fig. 1). Axis 1 reflected the significance of longitude and Mg content of soil. Axis 2 represents dominance of invasive species distribution (Fig. 3).

**Ordination using canonical correspondence analysis:** Vegetation data matrix was analyzed by CCA using geographic coordinates and soil data matrix as explanatory variables in each of the three land use types to relate vegetation with ecological attributes within the city. The division of Quadrats along two axes represents the influence of soil physico-chemical properties on vegetation. The CCA results showed that environmental variables accounted for significant amounts of variation in the floristic data, but differ considerably in the amount of variation explained in three land use types. The CCA explained 13.86%, 11.25% and 14.66% of the variation in built up, drain side and green areas.

Comparison of eigenvalues, percent variance explained, inter-set correlations and species environment correlations between soil physical, chemical and heavy metal properties along three axes are given in Table 2 while, CCA ordination plots are shown in Fig. 4, 5 and 6 respectively. Drain side community types correlated negatively with longitude while it was significantly correlated with the soil texture (Table 2).

Hierarchical vegetation gradient was dominant separating the tree structure from the herbaceous one dominant in the city centers towards left side of the ordination diagram. Separation of quadrats of *Broussonetia-Populus* community type on the right side of ordination diagram and *Panicum-Conyzanthes* community type on the left side of axis 1 indicate characteristic type of vegetation invasion along drain sides in the city (Fig. 4). Significant differences were reflected in the organization of both communities as the drain system is passing through whole of the city both from populated and green areas. This becomes the basis for the separation of two community types in drain side land use types on the ordination diagram.

Herbaceous species dominated the left side of axis 1 represented by *Panicum-Conyzanthes* community type. This type of vegetation dominated the drain side area passing between built up structures. Amongst chemical variables OM, Ca, Mg and K showed correlation with species distribution (Fig. 5). Along axis 1, Mg and K were significant while along axis 2 OM, $HCO_3^-$ and Ca were dominantly correlated (Table 2). Heavy metals (Ni, Cd, Cu and Co) also emphasized their importance on axis 1 dominated by the herbaceous community (Fig. 6). Responses of herbs to edaphic variables differed from the other community types as being influenced by anthropogenic activities.

*Broussonetia-Populus* Community Type was dominant in a region where sufficient space has been left as catchment side of drains representing the greener open areas of the city. Soil TDS and $HCO_3^-$ showed correlation with this community type while none of the heavy metals were found influencing the *Broussonetia-Populus* Community Type. This supported in its diversity and spread in open spaces along drain sides.

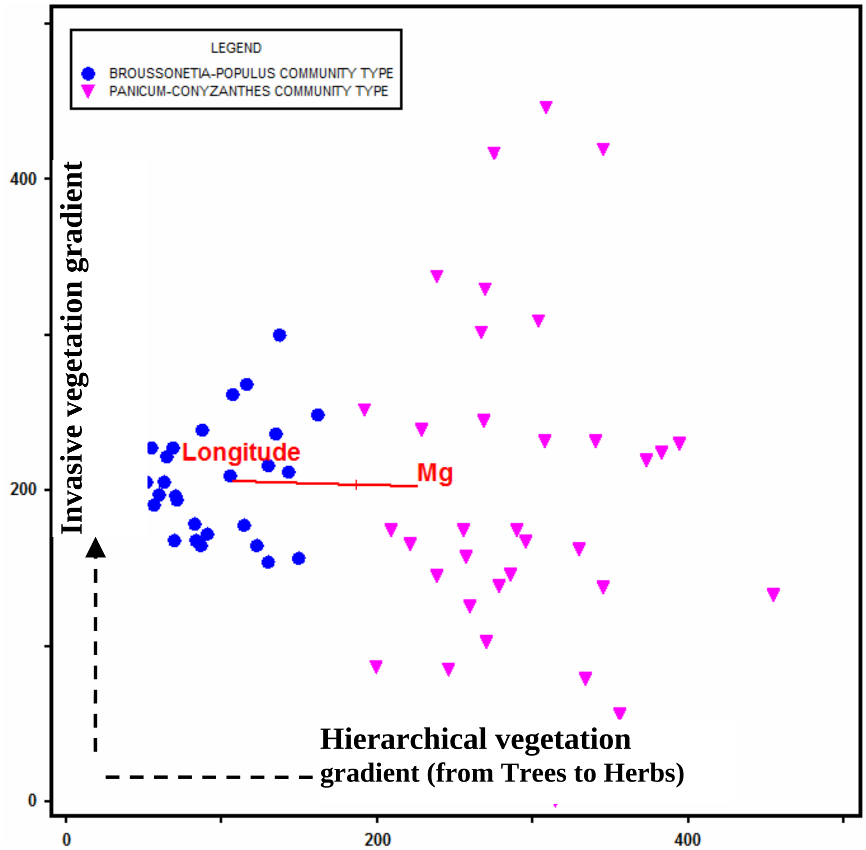


Fig. 3. DCA plot ordination of vegetation data of drain side area with an overlay of TWINSPAN Groups along two axes. (percent cover by species).

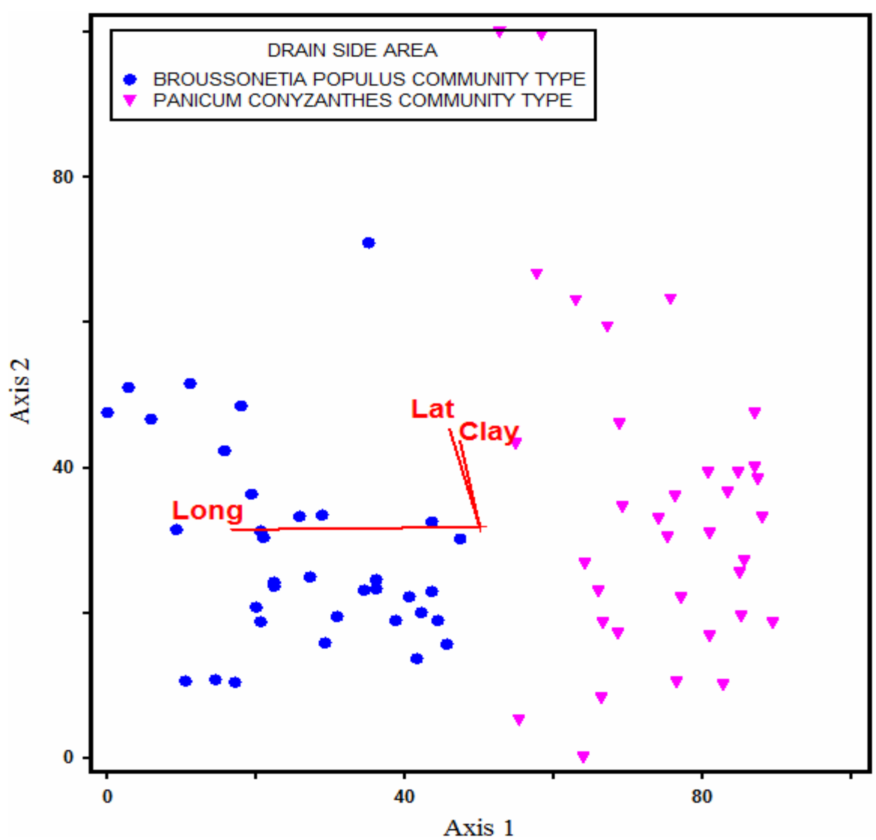


Fig. 4. CCA Plot ordination of vegetation data of drain side area using geographical coordinates and physical properties as variables (percent cover by species).

**Table 2. Inter-set correlations, comparison of Eigenvalues and species environment correlations between soil physical, chemical and heavy metals properties and CCA ordination axes in drain side areas.**

| | | Correlations | | |
|---|---|---|---|---|
| | | **Axis 1** | **Axis 2** | **Axis 3** |
| **Physical variables** | Latitude | -0.245 | 0.527 | -0.188 |
| | Longitude | -0.796 | -0.117 | -0.010 |
| | Sand | 0.223 | -0.202 | -0.725 |
| | Silt | -0.132 | -0.162 | 0.754 |
| | Clay | -0.162 | 0.492 | 0.110 |
| | Eigenvalue | 0.337 | 0.209 | 0.188 |
| | % of variance explained | 3.0 | 1.9 | 1.7 |
| | Commulative % explained | 3.0 | 4.9 | 6.5 |
| | P* | 0.05 | 0.01 | 0.09 |
| | Spp-Envt* | 0.811 | 0.808 | 0.819 |
| | Total variance ("inertia") | | | 11.25 |
| **Chemical variables** | Ph | 0.232 | -0.178 | -0.372 |
| | EC | -0.163 | 0.079 | -0.091 |
| | TDS | -0.420 | -0.010 | 0.016 |
| | OM | 0.004 | 0.561 | 0.034 |
| | $HCO_3^-$ | -0.199 | 0.336 | -0.540 |
| | Cl | 0.046 | 0.207 | -0.014 |
| | $No_3^-$ | -0.009 | -0.014 | -0.156 |
| | Ca | 0.064 | 0.390 | -0.172 |
| | K | 0.383 | -0.088 | -0.193 |
| | Mg | 0.578 | 0.084 | -0.144 |
| | Na | 0.061 | 0.086 | 0.385 |
| | Eigenvalue | 0.341 | 0.232 | 0.226 |
| | % of variance explained | 3.0 | 2.1 | 2.0 |
| | Commulative % explained | 3.0 | 5.1 | 7.1 |
| | P* | 0.24 | 0.84 | 0.54 |
| | Spp-Envt* | 0.816 | 0.847 | 0.780 |
| | Total variance ("inertia") | | | 11.252 |
| **Heavy metals** | Pb | -0.118 | -0.055 | 0.118 |
| | Ni | -0.638 | 0.271 | -0.114 |
| | Fe | 0.171 | -0.347 | 0.190 |
| | Zn | 0.134 | -0.169 | 0.009 |
| | Cu | -0.337 | -0.485 | 0.462 |
| | Cd | -0.531 | 0.037 | -0.379 |
| | Co | -0.496 | -0.327 | -0.400 |
| | Eigenvalue | 0.298 | 0.241 | 0.213 |
| | % of variance explained | 2.6 | 2.1 | 1.9 |
| | Commulative % explained | 2.6 | 4.8 | 6.7 |
| | P* | 0.21 | 0.15 | 0.10 |
| | Spp-Envt* | 0.835 | 0.836 | 0.756 |
| | Total variance ("inertia") | | | 11.25 |

*P = proportion of randomized runs with eigenvalue greater than or equal to the observed eigenvalue i.e., P = (1+no.permutations>=observed)/(1+no.permutations)

*Spp-Envt correlations refer to Pearson correlations between sample scores that are linear combinations of environmental variables and sample scores that are based on species data.

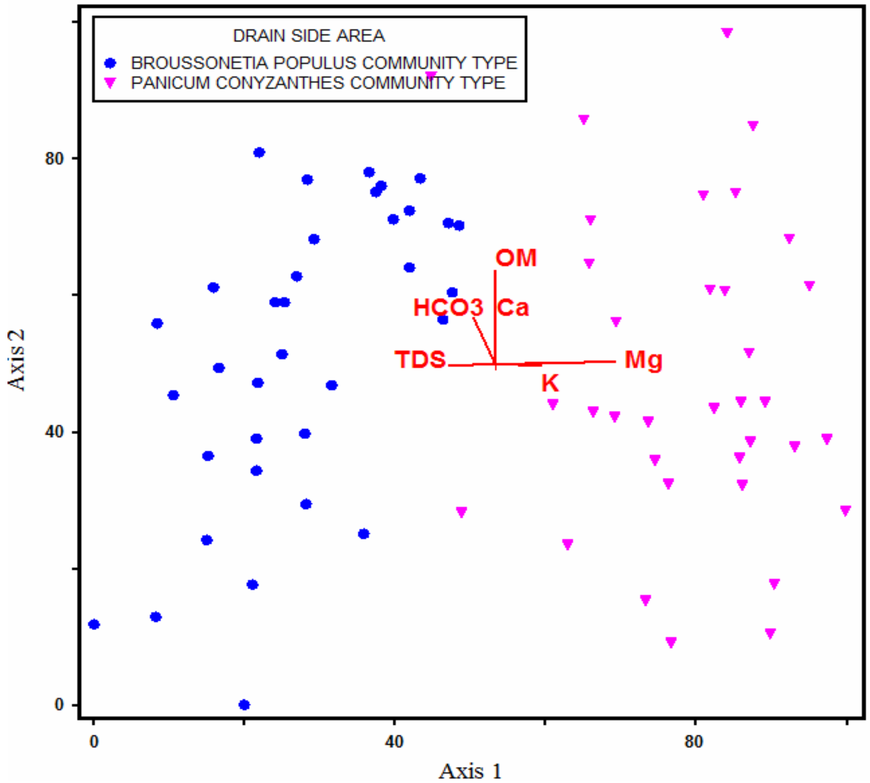


Fig. 5. CCA plot ordination of vegetation data of drain side area using soil chemical properties as variables (percent cover by species).

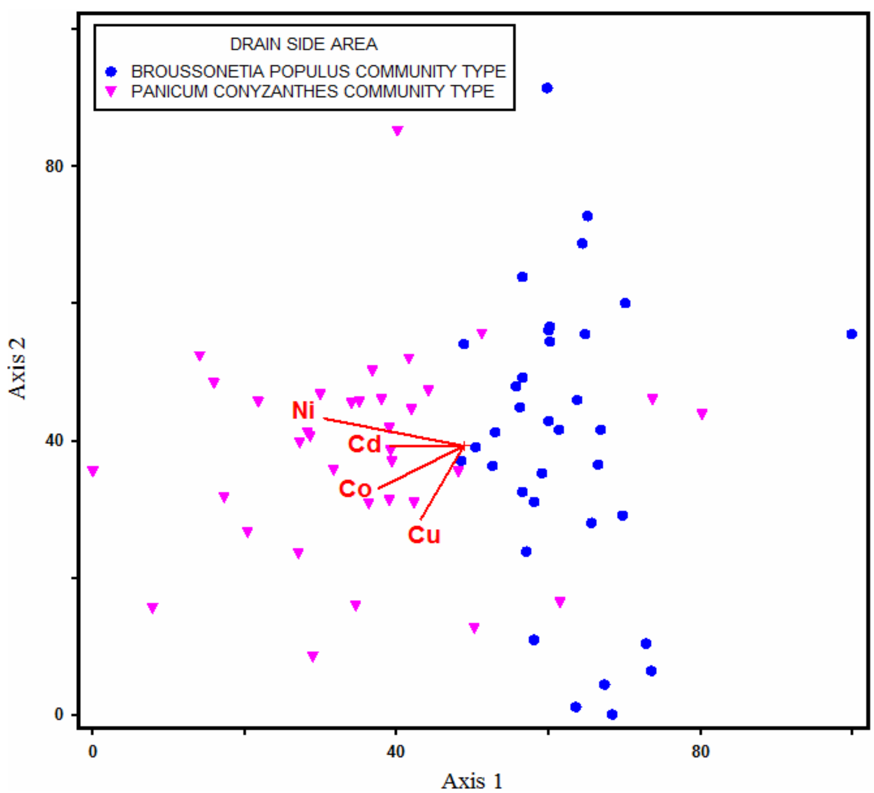


Fig. 6. CCA plot ordination of vegetation data of drain side area using soil heavy metal properties as variables (percent cover by species).

## Discussion

This study deals with vegetation soil relationship along drain side areas in a systemic way. Classification and ordination techniques were used as a mean of determining the ecological gradients and soil types in an urban structure (Kent & Ballard, 1988). Urbanization has led to mixtures of residual and introduced vegetation comprised of native and non-native species (Sudha & Ravindranath, 2000). Land use history along with spatial position has considerable explanatory power for floristic patterns. With an increase in population and construction activities in the studied area, there has been an expansion of herbaceous species and reduction of tree species in recent years.

Islamabad city was built in an area which was heavily forested land dominated mainly by *Acacia*, *Azadirachta*, *Morus* and *Carissa* species. With the increase in population, demand for land increased, and clearing of forested land was initiated. Later on trees such as *Eucalyptus, Ficus* and *Grevillea* dominated the tree flora of the city. The city also serves as a home to many annual and perennial plants including *Cannabis* and *Taraxacum*. Several flowering plants that are planted for beautification purpose like *Roses* and *Jasminum* species also contribute towards the city flora.

Dominance of *Cannabis sativa* and *Parthenium hysterophorus* was found along drains passing from the densely populated areas while tree species characteristic of drain sides such as *Populus euphratica* was found abundant in relatively open and broader sites. *Broussonetia papyrifera* and *Dalbergia sissoo* were relatively found in higher abundance in green areas. The important threatening invasive species introduced in the Islamabad city and observed during the survey were *Broussonetia papyrifera, Cannabis sativa, Eucalyptus globules, Parthenium hysterophorus, Prosopis juliflora* and *Lantana camara*. Vegetation of Islamabad city is under threat due to invasion/introduction of species. Natural factors such as soil and landscape diversity support the rapid growth of invasive species (Kühn *et al*., 2003). *Broussonetia papyrifera* has been recognized as one of the worst plants invaders of high impact in Pakistan which thrives along streams, nullahs and drains due to presence of high moisture content which favors its vigorous growth. This in turn results in excess water consumption decreasing the water table (Malik & Husain, 2006) ultimately resulting in lowering of species diversity of the area (Khatoon & Ali, 1999). During February until April proximity to *Broussonetia papyrifera* contributes to severe pollen allergy (Birsel, 2007). Pollen count during this period reaches approx. 40000 per $m^3$ causing severe asthma related problems to the local population. Due to its water loving nature it invaded along drain side areas of the city. Presence and relatively high density of invasive tree species can be attributed to CDA policy to import large number of plants since the establishment of the city for its beautification subsequently reducing the natural flora. Invasive species carries a risk of environmental damage therefore, it is suggested that species should be planted which do not affect the health of the residents in cities.

*Dalbergia sissoo, Acacia nilotica* and *Morus alba* and *Morus nigra* species were dominating tree species (Anon., 1980) before 1960's which were then eradicated as a result of human activities and introduction of some new species. *Broussonetia papyrifera* invasion is recognized as one of the factor that has transformed the species composition of the area from native to a mixture of introduced and native species. CDA has attempted to eradicate the plant by replacing it with some plant species of innate origin like *Bauhinia variegata* and *Cassia fistula* that are not only productive but also does not harm the already existing vegetation in the area and the results of their growth rate are extraordinary (Imran, 2004).

**Vegetation patterns and ecological gradients:** DCA and CCA ordination techniques provided similar results in terms of evaluating and interpreting the community types and supported the TWINSPAN classification results. The results indicated that the ordination analyses proved useful in confirming and clarifying vegetation relationships within and between the classified groups (Shupe, 2005).

The first DCA ordination axis reflected hierarchical vegetation gradient from trees to shrubs ordinating the samples from sparse to densely populated structure in urban areas relating it to urbanization gradient. Differences of species composition along drain sides can be attributed to space availability and favorable soil conditions for the growth of plants. Soil physico chemical variables also contribute in explaining the structure and distribution of floristic communities (Chang & Gauch, 1986).

The second DCA ordination axis revealed the effect of anthropogenic activities and introduction of exotic species in plant community types. The community types on the right side of ordination were less affected by human activities. The second largest group on the ordination diagram represents sparse herbaceous vegetation that is present in and around developed/constructed areas. The vegetation types are favored by invasion gradient. Presence of invasive species like *Broussonetia papyrifera* and *Parthenium hysterophorus* in the area is an indicative of a threat to the native vegetation contributing to changes in species diversity and vegetation composition (Ali and Malik, 2010). Also these species possess threats to human health due to their causal in pollen allergy which has become its cause of eradication to protect the natives of an area.

The ordination diagrams (Figs. 4-6) suggested transformation of vegetation structure from grasslands (left side of ordination) to woody sites (right side of ordination) that can be attributed to human related activities such as eradication of vegetation for construction and uneven distribution of plants for beautification purpose etc (Feng *et al*., 2005).

The vegetation type that prevailed along drain side of the city showed a large variation from those of residential sites (Fig. 3). Species diversity decreased from open green areas to residential areas along drains route. This is attributed to the construction and developmental activities at residential sites. Most ecological factors along with land use gradient account for significant fraction of species richness. In the study area CCA ordination provided that geographical coordinates and clay content were important variables in correlating with the community types of drain sides (Fig. 4). Soils of study area are mostly silty loam in nature that supports healthy growth of plants and has resulted in adequate plant diversity in the city area. The soils were found mostly basic in nature with pH ranging between 6.3-8 (Ali & Malik, 2010). Higher pH values have been reported in greater retention of metals in the soils of study area (Malik *et al*., 2010). Vegetation plays an important role in reducing nutrient leaching through nutrient adsorption and determines soil depth through holding of soil particles by plant roots. This is attributed to the soil OM and major nutrients like Ca, Mg and K that have a significant role in distribution of plant communities (Fig. 5). Species richness strongly correlates with organic matter (Vander *et al*., 2003). Urbanization has a great impact as it reduces the number of wastelands like garbage holes and dumps and replaces them with buildings, parks or urban greenery (Chocholouskova & Pysek, 2003). Mashaly *et al*., (2001) also indicated that soil EC, OM, soil texture, pH, Ca, Na, K and nitrogen content have been proved as important predictors for species richness in the Mediterranean regions of Nile delta.

Heavy metals viz., Ni, Cd, Co and Cu showed correlation with the representative herbaceous vegetation of drain sides indicating direct influence of anthropogenic activities owing to its presence in residential areas. The community types of drain side areas showed relatively high concentrations for Cd and Ni. Waste disposal along drain side areas was frequently found during field visits while, house hold waste coming to the drains contain broken batteries, cells, cigarette fragments etc., that contribute in Cd and Ni inputs (Hirata, 1981).

The results of the present study highlight the importance of preservation and conservation of green areas prevailing along drain sides. It can be generalized to other similar metropolitan cities of the region. The areas along drain sides are reserved in the Islamabad city for greenness which should be managed to support native species diversity. It is hoped that the results would be useful in order to conduct similar studies keeping in view the restoration of floristic patterns in urban drain sides.

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