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Soil and Vegetation Analysis of Selected Roadside Greenbelts in Rawalpindi City, Pakistan

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Abstract

Roadside urban greenbelts play an important role in increasing urban aesthetic, comport, and atmospheric qualities. This significant role of plants in urban roadside greenbelts cannot be denied. Therefore, a strong research is required to carve out the role of plants in both qualitative and quantitative terms for sustainable planning and management of urban areas. Unfortunately, Pakistan lags behind in such kind of research from other countries. The documentation of the planning of urban greenbelts is inaccessible and no proper reporting is available. In view of these facts, an attempt was done to assess three roadside greenbelts in Rawalpindi city in terms of their plants, their community formation and association with environmental parameters. The analysis through ordination techniques showed 2 major groups in each greenbelt with a significant association with EC, saturation, P, Zn, Cu and Mn. Few species showed affirmative response towards the environmental variables. The study provided base line data and information of plant communities. But it strongly emphasizes need of the comprehensive research on each of the multiple roles played by plants in such localities for the effective, sustainable planning and management.

Keywords: Greenbelts, vegetation, rawalpindi, soil parameters.

Introduction

Transportation corridors are major infrastructure elements of today's cities, and actions by transportation designers and planners have great influence on social ecology and community. Urban foresters, designers, and planners encourage roadside planting termed as "Roadside Greenbelts" to enhance the livability of urban areas as plants play a crucial role in the urban environment, fulfilling aesthetic, socio-cultural, ecological, health-promoting or economic functions. There are huge advantages of plants present in urbanized terrains, while negative aspects seem to be of minor significance and are due to incorrect choice of species and location. A multitude of functions and advantages of urban green areas speaks decidedly for their expansion and conservation[1,2]. The aesthetic and architectural role is an important function of plants in cities. By their diversity, they enrich the landscape and differentiate the perception of colour, structure and density of the surroundings depending on the season[3]. Urban roadside greenbelts also present social advantages, supporting mental and physical health. The economic benefits of the presence of plants in cities also cannot be disregarded. Depending on age, species and size of tree crown, trees can influence the value of properties in which they grow[2,3].

Roadside plants, because of their proximity to the generation of vehicle emissions, are important in reducing pollution. Beckett et al.[4] found that roadside plants capture more large-size particulate matter than plants away from road. Plants increase humidity and by transpiration and shading, they slightly lower local air temperature and thus ozone level, which tends to accumulate in places with higher temperatures. Plants minimize the negative impact of wind, fulfilling a role of windbreaks along streets and motorways[2]. They alleviate the impact of heavy rain by keeping raindrops on their leaves, thereby reducing run-off to drainage systems and minimizing the risk of flooding[1]. In addition, they provide protection from the sun, filtering much of the UV radiation reaching the earth's surface. In combination with soil banks and other structures, plants constitute a sound-absorbing barrier, which is important particularly along thorough fares and motorways[5]. Furthermore, trees are an oasis of biodiversity, securing feed and shelter for invertebrates, birds and mammals[2].

The value of plants in urban environment is now generally recognized not only aesthetically but also functionally in helping to make cities and towns agreeable places to live and work in. The first choice should be, therefore, to select easily propagated and readily available, medium growing, ecologically much suitable, pest and disease resistant tree species and also require less maintenance should be given top priority. With the advent of economic growth, the urban environment of Pakistan has become predominated by concrete high-rise structures and a place of congestion, both from traffic, and commercial activities. The degeneration of our living environment in urban areas is largely due to new housing and townships, electrification, widening of roads, industries, rush of the automobiles etc.[6,7,8] As a result, the balance of urban climate has been disrupted and most of the vegetation has been destroyed to make way for the so-called 'urban development'. It therefore

requires site- specific research in addition to special strategies and policies to govern its management and design.

Multivariate techniques proved to be best techniques for ecologist in classifying the vegetation and environment data. Because they bring samples and species closer together by occupying less dimensional space as compared to dissimilar species. Ordination is often used to discover and elucidate major axes on compositional variation in vegetation data. Larson[9] supported this fact that the interference in an area helps exotic plant species to get stabilize within the prevailing conditions. For the investigation of the vegetation composition TWINSPAN is widely applied[10-14]. In the survey of He et al.[15] the DCA (Detrended Correspondence Analysis) clustered five major groups of the species and the two major communities have characters in transition with other communities. Similarly, CCA (Canonical Correspondence Analysis) techniques were used to extract the response of species for soil moisture, EC, pH and organic matter[16].

The above relevant facts have brought the need of evaluating the assessment of green cover in an urban ecosystem. In this context the present study of roadside greenbelts analysis was undertaken in Rawalpindi city wherein 3 major roads were considered i.e. i. Mall Road ii. Rawal Road and iii. Airport Road (figure 1) due to nearby densely populated residential area and large number of daily vehicle transit. The city lies between 72° 38' and 73° 37' east longitudes and 33° 04' and 34° 01' north latitudes.

Methodology

Random sampling technique was assayed for the collection of plants from roadside greenbelts of selected roads. Total 15 quadrats of 1m x 1m were laid down in each greenbelt for herbaceous plants and trees were observed. The cover estimation was recorded by the "DOMIN" scale[17]. The species were identified from the literature. Composite soil samples were collected, tested and recorded. Soil moisture, EC, Organic Matter (O.M), pH and heavy metals were analyzed in order to show the relationship among species and these gradients. Allen method was applied for the evaluation of soil moisture[18]. Nikolsky Method[19] was used for the testing of organic matter. Hua et al.[20] method was applied for analysis of heavy metals i.e. Zn, Fe, Cu and Mn. Twinspan, DCA and CCA ordination methods were applied for the analysis and quantification of relationship of plants and environmental variables. ArcGIS 10 was used to spatially represent different soil parameters along with the interpolation through IDW (Inverse Distance Weighted) method.

Results and Discussion

Plant diversity in roadside greenbelts: Table 1 presents plant diversity observed in the roadside greenbelts in selected sample points. A total of 23 different species were observed and the diversity of species in Airport Road and Mall Road was greater as compared to the Rawal Road.

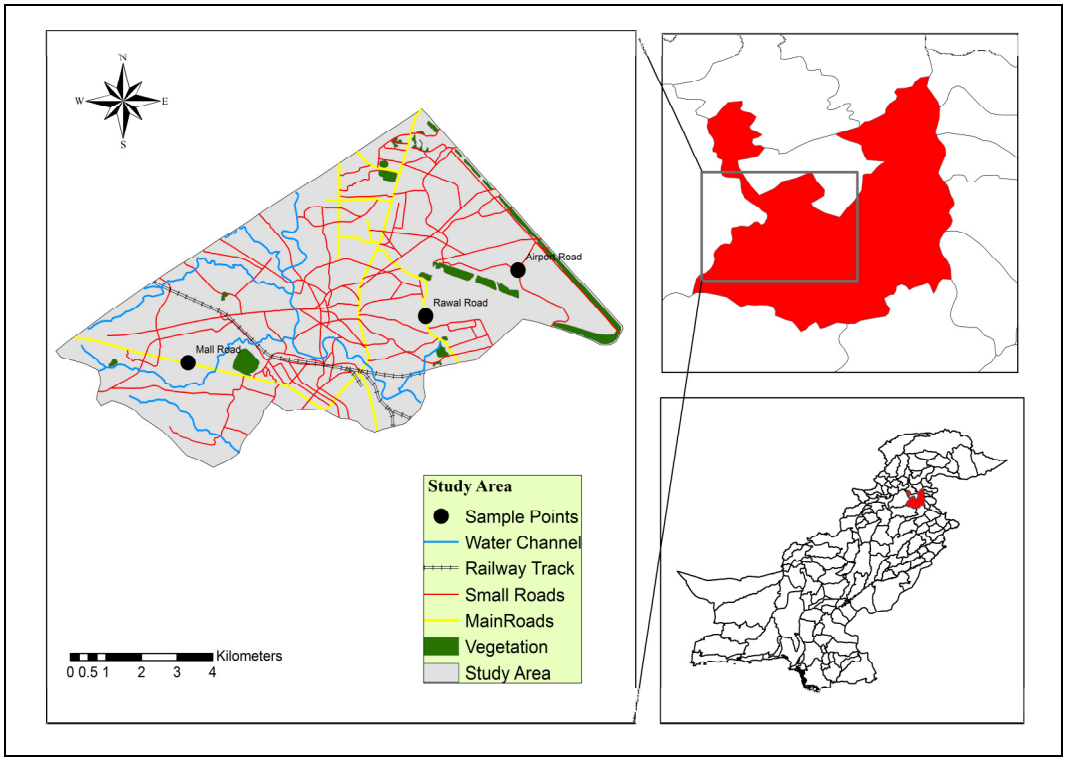

Figure-1
Study Area with selected roads for the study

Types of plants used in roadside green belts of selected roads represented variety of plant groups. These included flowering plant, attractive leaves plants and evergreen plants. The diversity of roadside plants provide advantage, due to the variety of species in the community of greenbelts more resist to pest attack and also increasing the physical quality of the environment.

Physico-chemical analysis of soil samples: The soil collected from the selected roadside greenbelts was tested for certain physical and chemical parameters. These parameters shown in table 2 were then interpolated by IDW method to assess the soil of nearby areas with the help of selected sites. The data was also used in CCA in order to show the effect of environmental factors on plant communities.

Tables-1
List of vegetation identified along the three road belts

Air Port Road			
Sr. No.	**Species**	**Common Name**	**Family**
1	*Calendula arvensis*	Field marigold	Asteraceae
2	*Verbina officinalis*	mosquito plant	Verbenaceae
3	*Sonchus asper*	spiny sowthistle	Asteraceae
4	*Madicago polymorpha*	toothed bur clover	Fabaceae
5	*Oxalis corniculata*	Sleeping Beauty	Oxalidaceae
6	*Conyza canadensis*	Horseweed	Asteraceae
7	*Conyza bonariensis*	Flax-leaf Fleabane	Asteraceae
8	*Cornupus didymus*	Lesser swine-cress	Brassicaceae
9	*Malva Parviflora*	cheeseweed	Malvaceae
Rawal Road			
1	*Cassia fistula*	golden shower	Fabaceae
2	*Thuja occidentalis*	White cedar	Cupressaceae
3	*Petunia alba*	-	Solanaceae
4	*Calendula arvensis*	field marigold	Asteraceae
5	*Nerium oleander*	oleander	Apocynaceae
6	*Bauhinia variegata*	Orchid tree	Fabaceae
7	*Jacaranda mimosifolia*	Black Poui	Bignoniaceae
Mall Road			
1	*Chrysanthemum leucanthum*	oxeye daisy	Asteraceae
2	*Cannabis sativa*	hemp; marijuana	Cannabaceae
3	*Euphorbia milii*	Christ plant	Euphorbiaciae
4	*Dalbergia sisso*	Indian Rosewood	Fabaceae
5	*Petunia alba*	-	Solanaceae
6	*Rosa indica*	Rose	Rosaceae
7	*Bougainvillea variegata*	paper flower	Nyctaginaceae
8	*Tagetes minuta*	black mint	Asteraceae
9	*Ailanthus altissima*	tree of heaven	Simaroubaceae

Table-2
Physico-chemical properties of soil

Sr.No.	**Variables**	**Air Port Road**	**Rawal Road**	**Mall Road**
1	E.C (dS/m)	0.75	1.28	3.3
2	pH	7.34	7.43	6.54
3	O.M (%)	0.3	0.36	0.41
4	P (mg/Kg)	4.3	28.9	19.1
5	K (mg/Kg)	100	140	120
6	Saturation (%)	35	40	35
7	Texture	loamy	loamy	loamy
8	Zn (mg/Kg)	1.32	0.96	1.18
9	Fe (mg/Kg)	3.66	3.98	4.16
10	Cu (mg/Kg)	0.16	0.08	0.1
11	Mn (mg/Kg)	4.14	4.36	4.48

The interpolation of above mentioned physical and chemical parameters of the soil through selected soil samples are shown below (figure 2). Figure 2a indicates the Electrical Conductivity (EC) of collected soil samples of selected greenbelts of the study. The observed EC of the Mall road was highest while that of Airport Road was lowest among the three. The interpolation range was from 0.75-3.29 dS/m. Figure 2b shows the interpolation of the selected greenbelts soil pH. The range of the pH of the area was 6.54-7.42. The lowest was of Mall road which was slightly acidic while the Rawal and the Airport roads fell in the same range which was greater than 7. The interpolation of organic matter (OM) shows that Airport road had the lowest while Mall road had the highest value among the three with overall range lying in between 0.30-0.40% (figure 2c). Figure 2d shows total soil saturation of the selected greenbelts with interpolation range of the region in between 35-39.9%. The Rawal road lied in the highest range while the other two in the lowest range. In case of the Available Phosphorus, the Rawal road had the maximum and the Airport road had the minimum among the three with Mall road lying in between the range (figure 2e). The interpolation range of the area was from 4.30 to 28.89 mg/Kg. The results of the Available Potassium were same as that of Phosphorous. Rawal road led the other two and Airport road had the lowest value (figure 2f). The total range of the area lied in between 100-104.4 mg/Kg.

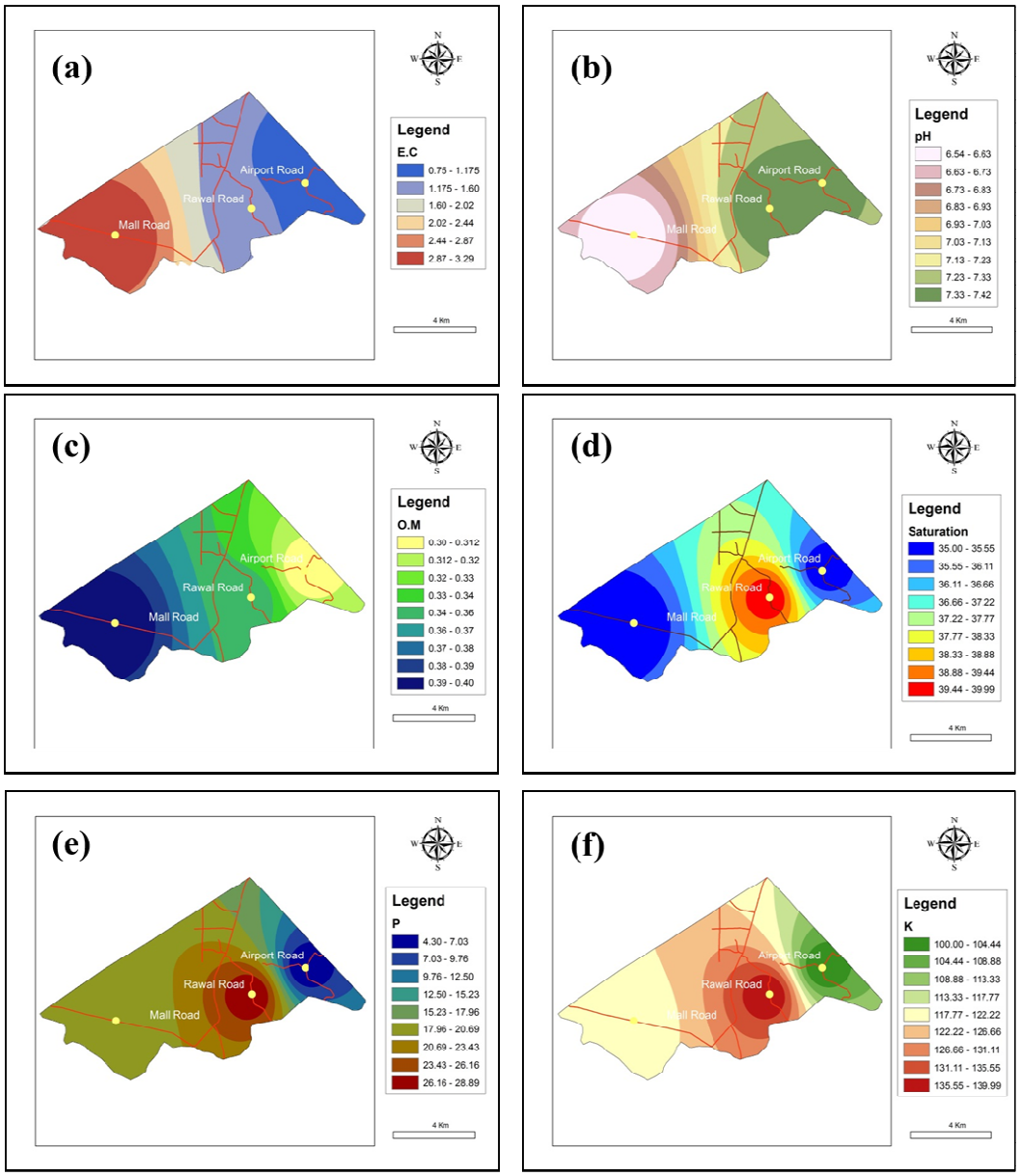

Figure-2
Interpolation of collected soil (a) EC (b) pH (c) OM (d) Saturation (e) P (f) K of selected greenbelts in Rawalpindi

Figure 3a shows that the interpolation range for Cu in soil of the selected greenbelts was in between 0.08-0.15 mg/Kg with Rawal road in the lowest range and Airport in the highest range. The interpolation range of the soil Fe of the selected greenbelts was 3.66-4.15 mg/Kg with Mall road having the highest concentration among the three (figure 3b). Figure 3c and 3d are the interpolation representation of the concentration of the Zn and Mn in the collected soil of selected greenbelts respectively. The concentration range for Zn was from 0.96-1.31 mg/Kg with Airport road having the highest concentration. While for Mn the interpolation range was from 4.14-4.47 mg/Kg with Mall road having the highest concentration among the three.

Vegetation Analysis: The vegetation analysis results are divided into three sections. Section one describes the overall vegetation pattern by TWINSPAN. Section two describes the grouping of different plant communities by DCA. Third section elaborates the relationship between various plant species and communities established with the various environmental factors using Canonical Correspondence Analysis (CCA).

TWINSPAN: TWINSPAN analysis was carried out for classification of plant communities using PC-ORD 5 which resulted in a two-way cluster dendrogram. Dendrogram was interpreted for two cut levels which further verified the result of TWINSPAN. A dendrogram is a hierarchical representation of species and stands in graphical form. The purpose of two way clustering was to graphically expose the relationship between cluster analysis and individual data. For Airport Road, total 15 plots were laid down and 9 species were identified from 6 families. Dendrogram classification divided the species into two major vegetation groups and one minor group (figure 4a). In Community 1 *Verbina officinalis* was abundantly present at first rank while in Community 2 *Conyza canadensis* was present abundantly at second rank. For Rawal road, out of 15 sample points, 7 species were identified from 6 families. Two major communities were identified (figure 4b). In Community 1 *Jacaranda mimosifolia* was abundantly present at first rank while in Community 2 *Cassia fistula* was abundantly present at second rank. In case of Mall road, 9 species were recognized from 8 families out of 15 stands. TWINSPAN demarcated two communities as (figure 4c). In Community 1 *Euphorbia milii* and *Ailanthus altissima* were abundantly present at first rank while in Community 2 *Bougainvillea variegata* was abundantly present at second rank.

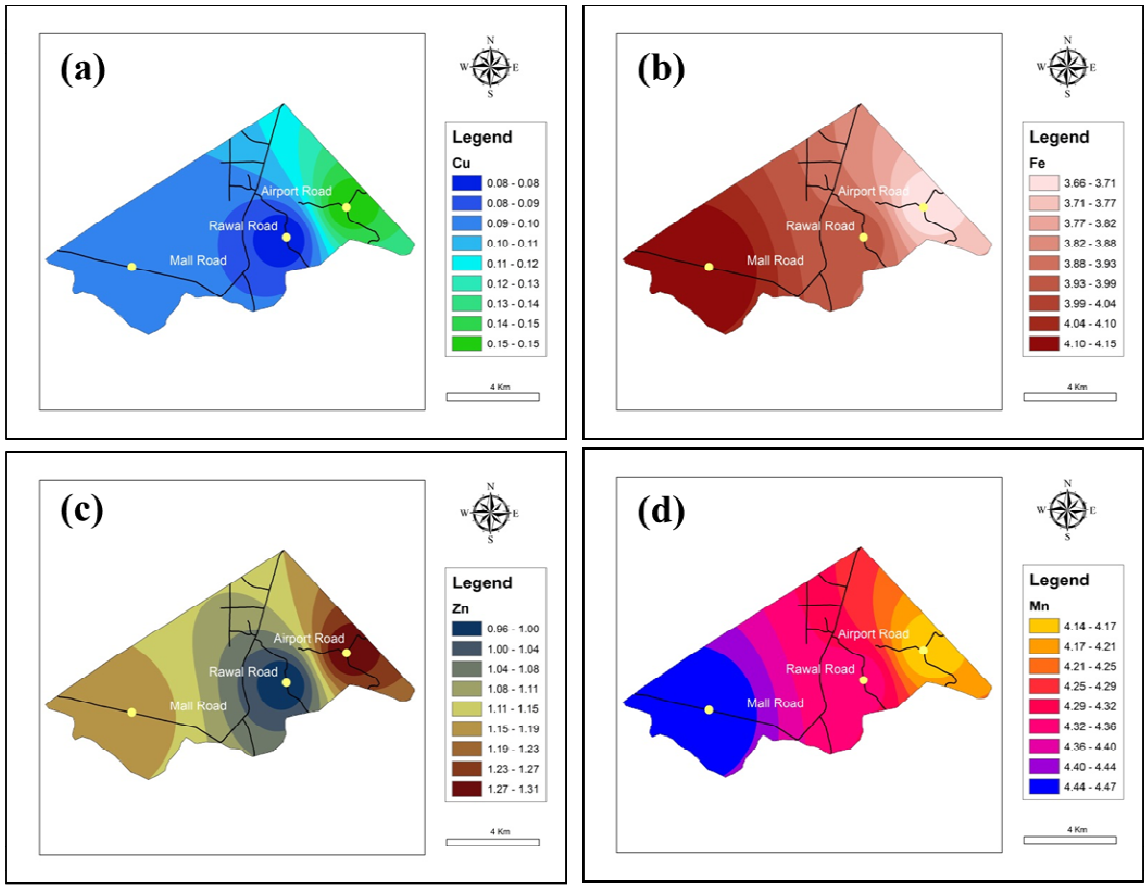

Figure-3
Interpolation of collected soil (a) Cu (b) Fe (c) Zn (d) Mn of selected greenbelts in Rawalpindi

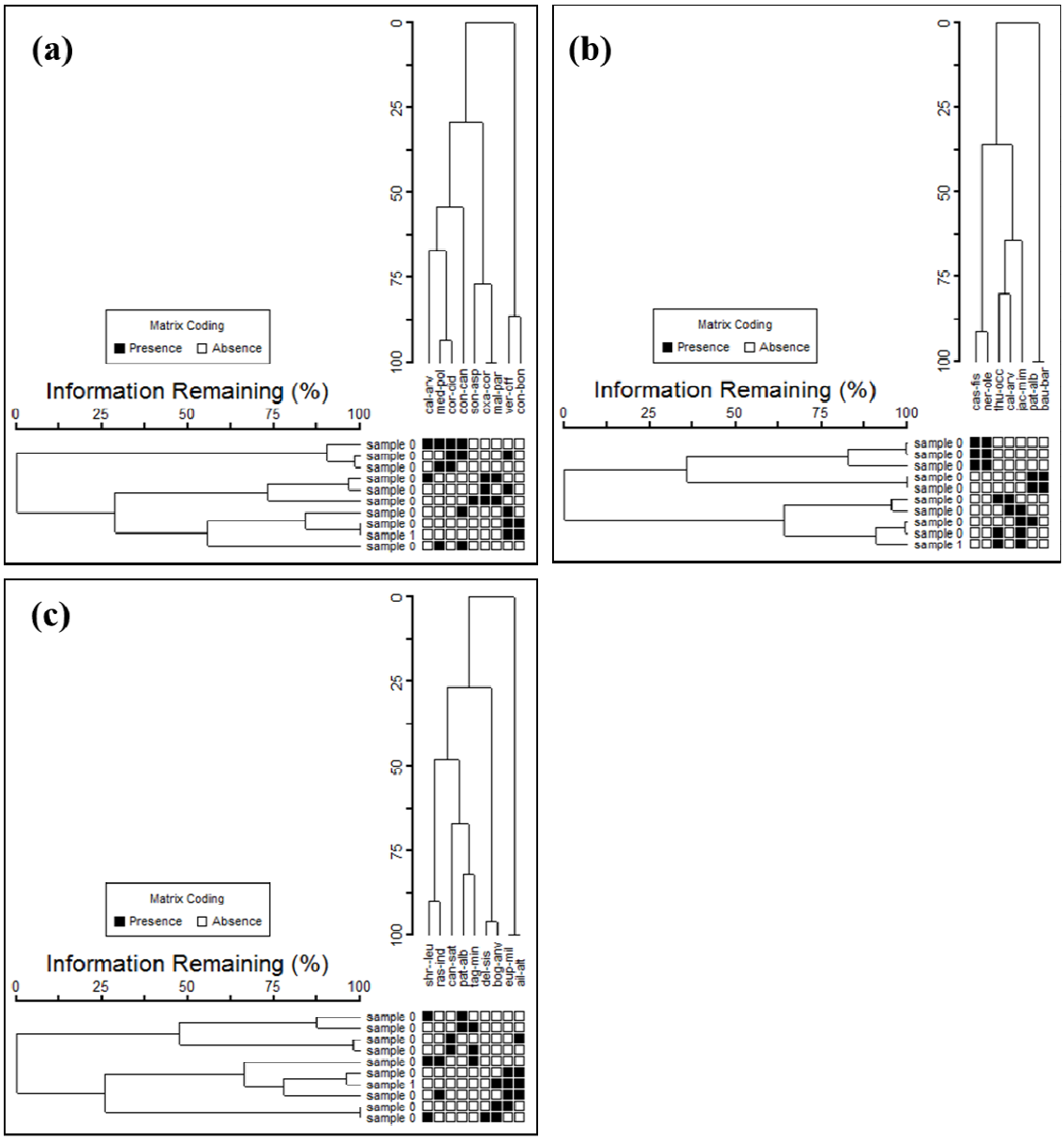

Figure-4
TWINSPAN dendogram of vegetation and samples of (a) Airport Road (b) Rawal Road (c) Mall Road

Detrended Correspondence Analysis (DCA): DCA is used to analyse the indirect ordinations. The distances between the points on the graph are taken as a measure of their degree of similarity or difference. Each point on the graph corresponds to species. The different occurring species with exactly the same abundance in the same quadrate would occupy in the same point. The distance between points on the graph represents the distribution of species. Detrended Correspondence Analysis (DCA) was performed for the further classification of species and it verifies the result of TWINSPAN. Species present in the graph were divided into groups. For Airport Road, three major groups were delineated by DCA as group 1, group 2 and group 3. The outliers were clearly marked in the graph as they did not participate in group formation (figure 5a). Goup 1 consisted of *Oxalis corniculata*, *Sonchus asper* and *Malva Parviflora*. Group 2 consisted of *Verbina officinalis* and *Conyza bonariensis* and Group 3 consisted of *Madicago polymorpha* and *Cornupus didymus*. In case of Mall Road, three major groups identified with demarcated outliers (figure 5b). Group 1 was comprised of *Euphorbia milii*, *Boganvalia variegate* and *Delbergia sisso*. Group 2 consisted of *Petunia alba* and *Tagetes minuta* and Group 3 was comprised of *Rosa indica* and *Chrysanthemum leucantha*. In case of Rawal Road, DCA analysis resulted in two major groups (figure 5c). Group 1 consisted of *Thuja occidentalis, Calendula arvensis* and *Jacaranda mimosifolia* and Group 2 was comprised of *Cassia fistula* and *Nerium oleander*.

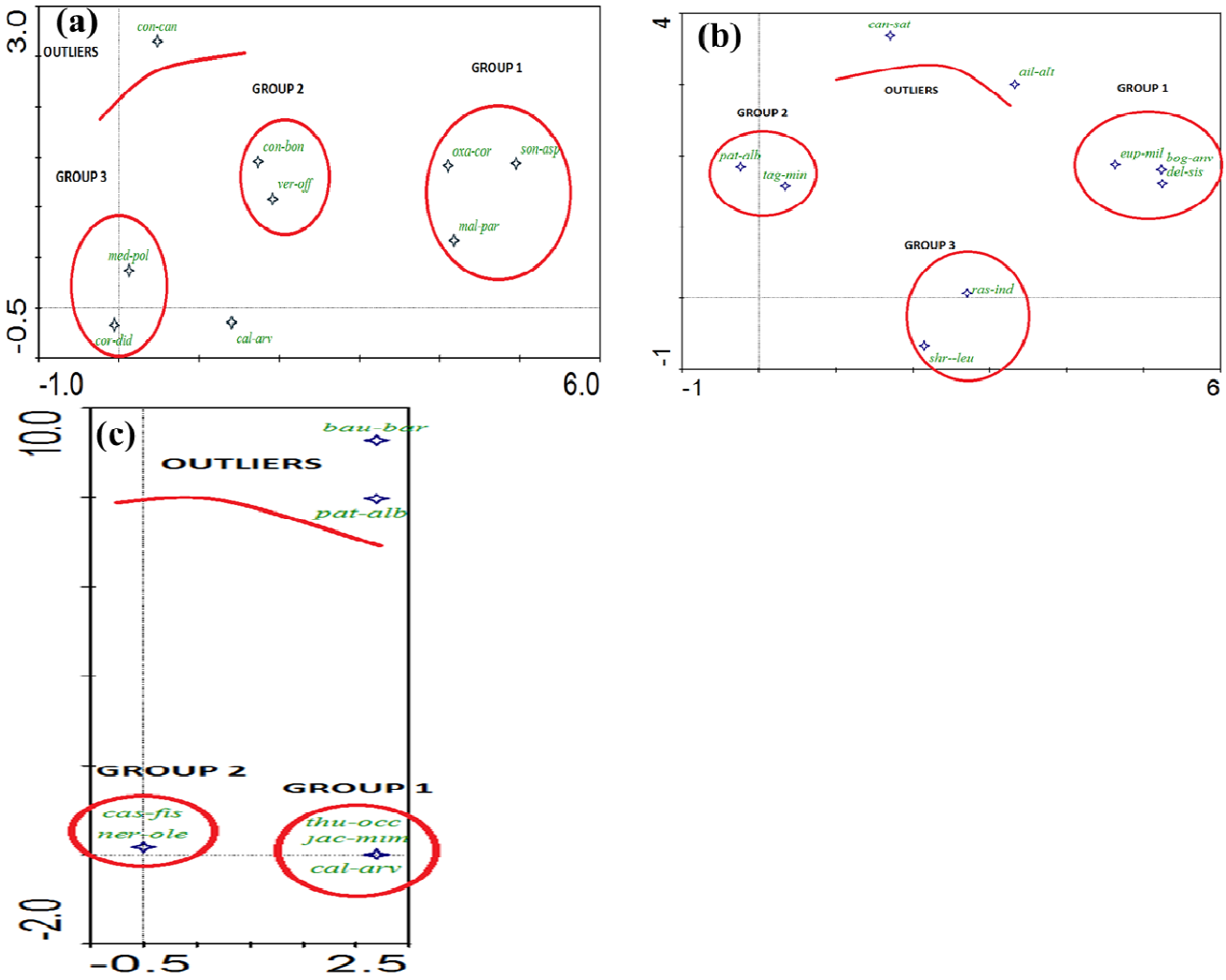

Figure-5
DCA analysis lay out with demarcated communities and labeled outliers for (a) Airport Road (b) Mall Road (c) Rawal Road

Canonical Correspondence Analysis (CCA): It is the most versatile technique of the multivariate analysis. The dispersion of the species in ordinate space for CCA analysis is same as the DCA analysis. The results of a CCA are shown in graphs of biplots. Biplots show relationship between environmental variables and species. The variables used for the species and environmental variables (soil) correlation included pH, organic matter (O.M), electrical conductivity (E.C), available Phosphorus (P), available Potassium (K), saturation and heavy metals i.e Zinc (Zn), Iron (Fe), Copper (Cu) and Manganese (Mn). Stars represent individual species. Arrows represents the environmental variables. The length of arrow is equal to the magnitude of change in that direction. Environmental factors that has long arrow are more closely related so called in the ordination than those with short arrows. The increased length of an arrow shows that it may be influencing the individual species. In graph showing CCA for Airport Road, E.C arrow had the longest length which was depicting the strong effect on the growth of the species. *Verbina officinalis, Malva Parviflora* and *Conyza bonariensis* lied close to the arrow head of E.C which means these species were closely correlated with the E.C value and were highly affected by the E.C change. While *Calendula arvensis* was closely related to saturation. The arrow of pH showed very little influence as its length was very small and no particular species was observed around this (figure 6a). In case of heavy metals *Calendula arvensis* and *Cornupus didymus* showed great association to Mn while *Verbina officinalis* to Cu and *Madicago polymorpha* and *Conyza* Canadensis were correlated to Zn (figure 6b). The distribution of the species with respect to environmental variables indicated that although most of the variables were strongly correlated, but they failed to play a major role in the grouping together of the species.

The CCA of Rawal Road showed that saturation and pH had no effects on the vegetation as they had the shortest arrows. While E.C and P had the longest arrows and vegetation around them was affected by these two variables. *Cassia fistula* and *Nerium oleander* were associated to P and *Thuja occidentalis* and *Jacaranda mimosifolia* were correlated to E.C (figure 7a). In case of heavy metals *Nerium oleander* was affected by Zn while *Cassia fistula* was correlated to Mn (figure 7b).

CCA of Mall Road showed that *Tagetes minuta* was associated to pH and *Petunia alba* was correlated to P while all other variables were not associated with any other species but had influence on them (figure 8a). In case of heavy metals, *Bouganvalia variegate* was associated to Mn, *Cannabis sativa, Petunia alba* and *Tagetes minuta* were correlated to Zn and *Ailanthus altissima* and *Delbergia sisso* had an association with Cu (figure 8b).

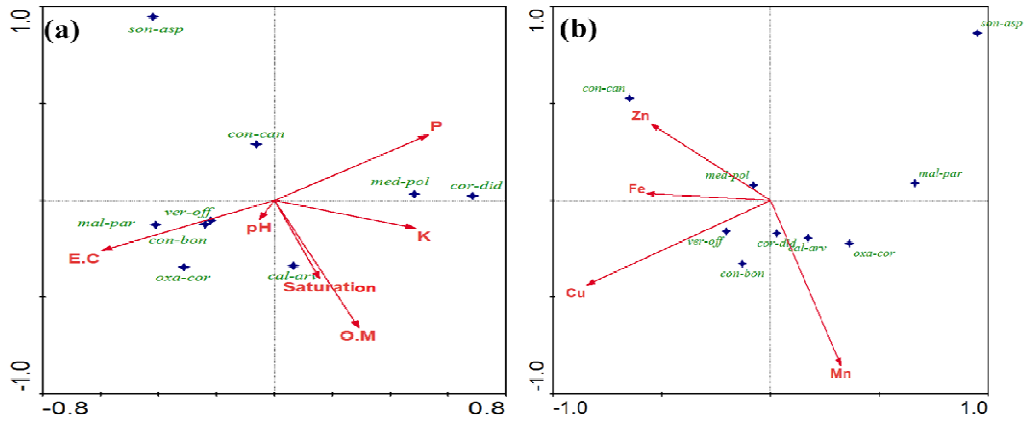

Figure-6
Biplot between (a) soil parameters and vegetation (b) heavy metals and vegetation along Airport Road

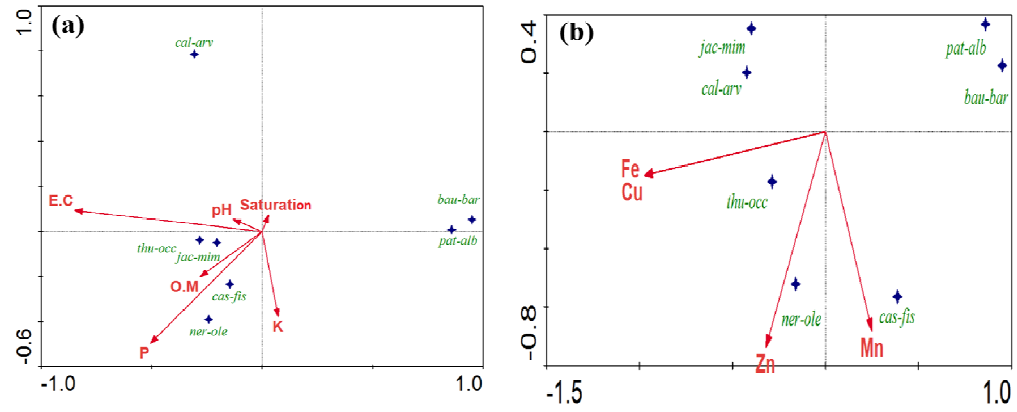

Figure-7
Biplot between (a) soil parameters and vegetation (b) heavy metals and vegetation along Rawal Road

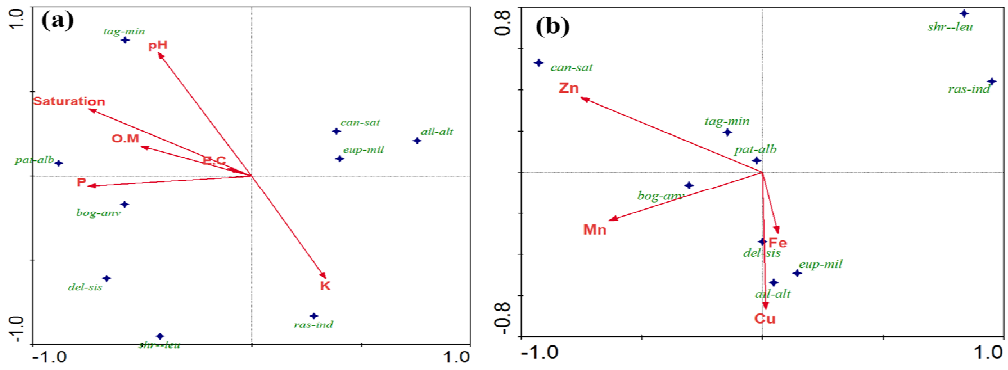

Figure-8
Biplot between (a) soil parameters and vegetation (b) heavy metals and vegetation along Mall Road

Discussion: Plants are vital for us because of the various biological activities are being performed by them[21]. Vegetation studies rationalized the steps for selection of best conservation, management tools and strategies to be applied for sustainable planning and utilization of natural resources[22]. The present study was conducted along urban roadside greenbelts to identify the plants/ trees used and their impact on other plants of the community. Three busiest roads of the city were selected i.e. Airport Road, Rawal Road and Mall Road, from the perspective of daily transportation, keeping in mind the other analysis of the study i.e. relationship of plants with environmental variables. A total of 23 species found from 45 quadrats (15 quadrats for each site). Moreover, it was observed that some of the wild plants were also identified along with the ornamental plants.

Soil analysis with selected physical and chemical parameters with its spatial variability was an important part of this research. Spatial variability in certain soil parameters can have influence on the spatial distribution of crop productivity potential. Spatial variability in soil physical properties, chemical properties, nutrient levels, and water content has been well documented[23,24]. Soil texture is very important for the growth of plants, as main function of water absorption. Water retention and intake of air etc. determine fertility of soil. The texture of the soil was loamy. For the purpose of estimating the fertility of the soil, EC, was measured because the process of EC carried out on clay particles of the loam[25]. Higher concentration of K was found in study area but it did not show marked contribution for the species response. Soil of urban belts was found to be slightly acidic to neutral as it ranges from 6.54 to 7.43. It has the effect over EC because the negative relationship between pH and EC was observed by Regassa[26]. The concentration of four heavy metals in soil also ranged from 0.10-4.48.

Multivariate techniques were further applied in this research to observe their relationship with the vegetation in the selected areas. Two Way Indicator Species Analysis (TWINSPAN) was applied for general classification of species which resulted in a two way cluster dendrogram. TWINSPAN identified overall 2 major communities from each urban belt. Similar classification technique delineated four vegetation groups of 52 herbaceous species of Margalla Hills National Park, Islamabad, Pakistan[27]. Detrended Corespondence Analysis (DCA) found association of few species with each other within a single community as well with the species of other community and species away from the clusters are outliers. Ahmad et al.[28] reported the ubiquity of these species. The results indicated by DCA suggested that there were no significant variation in abundance between the species to sample composition. However, along with the presence of abundant species some less frequent species were also shared the same distance in the central position of the scattered plot of DCA and CCA indicated that these species did not have specifications for the particular habitat but because of their ecological amplitude they had shown in sub grouping[27]. This appraisal found that most influencing factors for species growth and richness were saturation, EC and P; Zn, Cu and Mn were closely associated with the vegetation. Zare et al.[29] reported that in arid and semi arid environment the soil texture, salinity, organic matter, soil moisture were those gradients which had main effect on composition, abundance and distribution of species. Gower and Hand[30] reported that biplots can be generated by using CCA technique by inverting raw statistics. EC, moisture and organic matter found to be optimum for the growth of species. The abundance of the species declined with even small change in soil pH.

Conclusion

The aim of the present research was to observe, identify and evaluate the relationship of plant communities with environmental variables along 3 selected urban roadside greenbelts. The selected roadsides were among the busiest roadsides of the city heavily loaded with traffic. The results of the linkage showed that a few of the plant species were associated with each other and affected by the environmental factors. The multiple roles played by the urban roadside greenbelts emphasize the need of a comprehensive research for the effective planning and utilization of environmental friendly trees.

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