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CANONICAL CORRESPONDENCE ANALYSIS OF THE RELATIONSHIPS OF ROADSIDE VEGETATION TO ITS EDAPHIC FACTORS: A CASE STUDY OF LAHORE-ISLAMABAD MOTORWAY (M-2)

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Abstract

A survey of roadside vegetation and soils along Lahore-Islamabad motorway (M-2) was undertaken and the data were subjected to Canonical Correspondence Analysis to investigate the vegetation structure and its relationships to the selected edaphic variables. In addition, the patterns of plant species distribution in the whole study area and its different regions were also determined. CCA ordination was performed on a matrix containing % age cover value for all species (n = 227 species) on 397 sampled plots. This relationship was determined by ordination analysis. The environmental variables selected for analysis were organic matter, sodium, potassium, calcium, magnesium, total nitrogen and trace elements like lead, zinc, nickel, cadmium, chromium and iron. In CCA analysis of all the quadrats, chromium, zinc, lead, nickel, sodium and potassium were the most important variables influencing the quadrats distribution. The study also provides basic information for the implementation of conservation oriented planning and management to preserve and improve the road verges of M-2.

Introduction

The most recent development in ordination techniques is Canonical Correspondence Analysis (CCA) developed by Ter Braak (1986). It examines relationships between species distributions and the distribution of associated environmental factors and gradients. CCA differs from this classical indirect approach because it incorporates the correlation and regression between floristic data and environmental factors within the ordination analysis itself (Ter Braak, 1988). CCA is best defined as method of direct ordination with the resulting ordination being a product of the variability of the environmental data as well as the variability of the species data.

Many studies in different parts of the world described the application of CCA in the ordination methods as a useful tool. Daiyuan *et al.,* (1998) used CCA to evaluate the relative importance of edaphic factors in explaining the variation of species assemblage and to identify the ecological preferences of species in Xinjiang, China. Jonathan and Cynthia (2002) employed CCA to correlate woody vegetation of riparian forest, Missouri, USA, with several environmental gradients like elevation, soil pH, soil moisture and soil particle size. Arbelaez and Duivenvoorden (2004) while studying plant species compositional pattern on Amazonian sand stone on troops in Columbia used CCA to separate the effect of habitat and spatial configurations of the plateaus on species patterns. Similarly in Denmark, deciduous forest species were subjected to CCA to quantify the relative amount of variation in species composition attributable to geographical and environmental variables (Graae *et al.,* 2004). Ahmed & Jabeen (2009) used CCA to determine the soil vegetation relationship and quantify the floristic composition of National Park vegetation data of Ayub National Park. Ahmed *et al.,* (2009) used multivariate techniques to evaluate ecological aspects of roadside vegetation around Havalian city. Akbar *et al*., (2009) applied CCA on floristic and environmental data to ascertain the determinants of floristic composition of roadside vegetation in north England. Ahmad (2009) carried out study on the growth, distribution classification and correlation of herbaceous edaphic factors in Margalla Hills National Park, Islamabad. Pirzada *et al*., (2009) used multivariate techniques for lead pollution monitoring of selected roadside plants (*Dalbergia sisso* and *Cannabis sativa*).

The present study demonstrates the floristic survey of road verges alongside M-2 motorway and mainly focuses on the determination of vegetation structure and its relationships with some edaphic variables by using a direct ordination method. The overall goal of the recent work was to provide a more holistic assessment of the ecology of the roadside verges in the study area, which is expected to provide a better understanding of the various aspects of ecology of roadside verges.

Materials and Methods

To ascertain overall patterns of plant species distribution based on environmental variables, CCA ordination was performed on a matrix containing % age cover value for all species (n = 227 species) on 397 plots. Similarly, CCA was also performed on regional data in Region I, II, and III having 120, 80 and 197 plots respectively. For Canonical Correspondence Analysis, the computer program CANOCO (Ter Braak, 1988) was used with default options. This program has the capacity to analyze data of 500 samples. The environmental variables selected for CANOCO analysis were organic matter, sodium, potassium calcium, magnesium, total nitrogen and trace elements like lead, zinc, nickel, cadmium, chromium and iron.

The following criteria were followed during the selection of sites for the survey of roadside vegetation.

1. Plots were located systematically at 7 km intervals.
2. Sites with an established cover of vegetation along the verges were sampled only.
3. The disturbed roadsides (vehicle accidental area, fire effected area, oil leaked area etc) were avoided. If neither side of road was suitable, then the nearest suitable site within I km distance was selected. If no suitable site was available within 1 km, the sample point was omitted.
4. The total number of sampled stands is 50 and comprises of 397 quadrats.

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Zonation of road verges: During the pilot stage of survey, it was observed that in general, vegetation on the road verges could be divided into certain zones based on the variation of conditions and homogeneity of vegetation. Dowdeswell (1987) divided a typical road verge into outer zone, inner zone, ditch and bank or lope.

A site normally comprised of two zones:

Zone 1

Border zone: The road shoulder adjacent to the edge of road sealing. It was usually 1-3 m wide; soil is comparatively affected by traffic.

Zone 2

Verge zone: The fence zone which was demarcated from the adjacent private or state owned land by fence.

Plant data collection: For the collection of vegetation data Braun-Blanquet's approach (Braun-Blanquet, 1932) was used, which is still recognized worldwide. In this approach, sampling is done by the use of relves / quadrats, which are vegetation samples that are not randomly located and carefully selected as representative area of a vegetation type (Kent and Coker, 1992).

Size of quadrats: A suitable size of quadrat is important for vegetation sampling. It is selected according to the size and spacing of plants. Based on the usual observations of vegetation structure, which comprised mostly of herbs and grasses, the quadrat size of 1 x 2 m^2 was selected. A 100-meter long tape was laid down parallel to road randomly in each zone of the verge at each site.

One quadrat of 1 x 2 m^2 was selected at the start of long laid tape as border zone and second at last point of border zone. Two quadrats were laid along tape in verge zone. The same method was applied on both sides of road.

Results and Discussion

The eigenvalues for the two CCA axes are given in the Table 1. This table provides a comparison of eigenvalues and environmental variables correlation with the two axis of CCA ordination. The eigenvalues for the first two axes (λ 1 = 0.194 and λ 2 = 0.158) indicate separation along two axes. The first two axes are by far the most important in explaining the variation in floristic data because these explain 100% of total variation.

Table 2 shows the canonical coefficients of different environmental variables with the principle CCA axes. Axis 1 most closely corresponds to lead, chromium, and zinc with canonical coefficient values of 0.75, 0.65 and 0.58 respectively. Whereas nickel (-0.297) and iron (-0.48) showed maximum correlation with axis 2. Since the first two axes are the principle axes for explaining the variation in data, therefore the variables, which correspond strongly with these axes, are considered as the most important environmental variables.

Ordination of plant species: For ordination of plant species, all the recorded plant species (227) were used in CANOCO analysis to find grouping among the species. The results of species ordination are presented with more than 10 % of frequency values in overall study area i.e. 397 quadrats (Fig. 1). Each dot in the figure represents a species and the distance between the species indicate the similarity of species in their occurrence in the quadrats. In Fig 1 species names are given along with dots.

The differences in the patterns of the species distribution is illustrated by the CCA species plot and among them only 15 species have more than 10 % of frequency in the whole study area (Fig. 1). Four arbitrary main species groups are recognized on the basis of their positions in the figure and are designated as I, II, III and IV as shown in Fig. 1. Species in each group were represented by different symbols and names were mentioned along each dot representing species score. The species group I, II and III clearly indicate the separation of three major groups of species. The further division of three major groups in group I, II and III depends upon the relative occurrence of species in quadrats of different regions examined in the whole study area.

The group I comprises of three major species *Dodonea viscosa, Dactylocotenum aegypticum* and *Capparis decidua.* These species showed maximum percentage cover value and relatively good frequency value in Region I as well in the Region II. Among them *Dodonea viscosa*, an evergreen shrub, grows in sandy and stony soils as it made its appearance in Salt Range quadrats. *Dodonea viscosa* was also proved to be pollution tolerant; the Salt Range exhibits more pollution level than Region I and Region II in the present study. Similarly *Capparis decidua* that was also regarded as thorny shrub of waste areas and *Bothriochola pertusa* proved to be beneficial for erosion control and grows in poor soils in comparatively dry areas. All these four species showed quite a common characteristic and were grouped together due to their preference for common habitat.

The group II comprise of plant species showing highest cover value in region I. The prominent species in this group were *Cynodon dactylon, Calatropis procera* and *Cenchrus ciliaris.* Among them, *Cynodon dactylon and Cenchrus ciliaris* (African foxtail grass), prefer a highly disturbed and poor habitat. With the construction of motorway in this area, these species had grown successfully; whereas *Calatropis procera*, commonly known as roadside weed also got its natural habitat along motorway to grow in the study area abundantly. In Australia it was also regarded as weed of roadsides. The area in Region I mostly comprises of relatively dry sub-mountains. Most of these species exhibited low and compact growth form, which is advantageous to their survival in the existing conditions. The dominance of *Cynodon dactylon* was mainly supported by the fact that this perennial grass growth rate is very fast and within four month it completes its life cycle which makes it quite aggressive in nature. Similarly perennial rhizomatic *Cenchrus* quickly forms a mat and increases its cover area. That is why both species are grouped together.

The major species of group III includes *Cleome viscosa*, *Launea procumbens, Convolvulus arvensis* and *Sonchus asper*. This group includes species common in Region I and II. Therefore this group can be termed as transitional group of Region I and II species. Although the % age frequency value of these species was not quite high as that of group I and II, but they were grouped together by CCA due to their likeness of preferences. This occurrence together of these species and shorter distance between them clearly indicates coherence in their ecological amplitude. Both *Sonchus asper* and *Cleome viscosa* were regarded as common along roadsides, railroads and disturbed lands. *Cleome viscosa* is an indigenous species of Asia (Wagner *et al*., 1999), whereas *Convolvulus arvensis*, a climbing weed and *Launea procumbens* in this group indicates its similarity of ecological amplitude.

Table. 1 Summary of Canonical Correspondence Analysis results for whole study area.

Axes	Axis 1	Axis 2
Eigen values	0.162	0.140
Percentage variance of species-environment relationship		
For Each Axis	0.565	0.489
Cumulative	1.054	

Table 2. Comparison of Eigenvalues and species-environment correlation between environmental variables and CCA ordination axes.

Number of plots 397
Number of species 227

Variables	All plots	
	Axis 1	Axis 2
Organic matter	-0.092	0.282
Na	-0.367	0.171
K	-0.225	-0.071
Ca	0.074	-0.086
Mg	0.208	-0.082
T. Nitrogen	0.028	-0.029
Fe	-0.092	-0.48
|P	-0.354	-0.157
Zn	0.58	-0.478
Pb	0.75	0.087
Ni	0.323	-0.297
Cd	0.324	-0.067
Cr	0657	0.441
Species-environment correlation ψ	0.645	0.6444

ψ refers to pearson correlation between sample scores that are linear combinations of environmental variables and sample scores that are based on species data. All correlations listed below are "intraset correlation" as described by Ter Braak (1986)

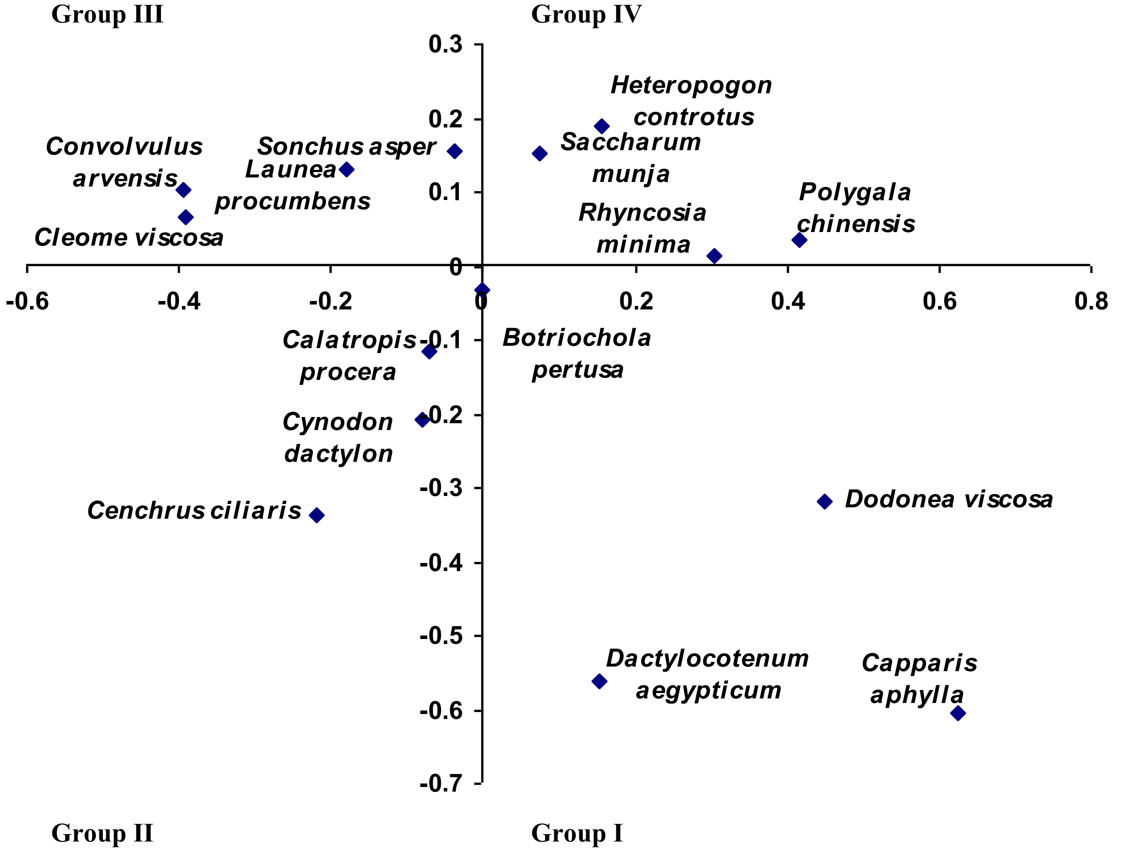

Fig. 1. CCA plots of species having more than 10 % of frequency value.

The group IV comprises of *Heteropogon controtus, Saccharum munja, Polygala chinensis* and *Rhynchosia minima*. All the species occur in the Region III of the study area that mostly consisted of flat area. *Saccharum munja* among them showed more than 10 % of frequency and occurred in 41 quadrats out of 397, but its high cover value made it a part of group III. Similarly *Rhynchosia* and *Polygala* also appeared in 65 and 43 quadrats respectively. This group comprises of species of low occurrence, but high cover values. Only *Heteropogon controtus* appears in 76 quadrats and is most dominating species in the group. Among the exclusive species of this group both *Heteropogon controtus and Rhynchosia minima* are perennial in their nature and are quick growing cosmopolitan plants. Their grouping together was supported by their ecological similarities.

Roadside vegetation and environmental variables: In the CCA biplot of all regions quadrats most of the quadrats are clustered around the center of the Fig. 2 indicating a lack of any definite grouping of vegetation, i.e., major community or sub-communities. The impact of any environmental variable in grouping together of vegetation groups is not well pronounced. Overall the impact of heavy metals along with sodium, potassium and phosphorus seem to influence the orientation of quadrats along two axes.

In the CCA of all the quadrats, chromium, zinc, lead, nickel, sodium and potassium were the most important variables influencing the quadrats distribution. On the positive side of the axis 1 relatively few quadrats scattered and heavy metals seem to have pronounced effect upon them. Whereas on the negative side of axis 1 most of the quadrats assemble round the origin of the axis under the influence of sodium, phosphorus and iron. While going through the axis 2, it appeared that most quadrats clustered around origin of axis on negative side, indicating the strong influence of organic matter and potassium upon them. The quadrats grouped on the positive side of axis 2 indicating the impact of nickel, magnesium and total nitrogen. The grouping together of quadrats on lower side of scattered plot, i.e., axis 1 positive side and axis 2 negative sides indicates a strong impact of basic mineral nutrients upon them.

By analyzing the pattern of species and quadrats distribution and relating them with ecological characteristics of the habitats supporting them, general pattern of variation was evident in the motorway vegetation. This pattern of differentiation exists involving to some extent, variation according to regional locations. Though roadside vegetation was strongly detrended by anthropogenic activities, regional differences are however just as important. This had also been shown by other workers in other countries. In California, distinct regional differences were found in the floristic composition of roadside vegetation and composition of roadside plant communities was found to vary according to regional vegetation and surrounding areas (Frenkel, 1970). In west Yorkshire, Rodwell (1994) described the main grasslands types and reported that mesotrophic grassland communities are common grassland types of pastures. In the present study, the complete dominance of grass species with the exception of few sites indicates the absence of any particular environmental variable influencing the distribution of species. However the occurrences of relatively few numbers of dominant or frequent species in the present study also support the fact that these species had wide ecological amplitudes and they were present throughout the study area. This fact has been supported by many workers (Ullmann & Heindle, 1989).

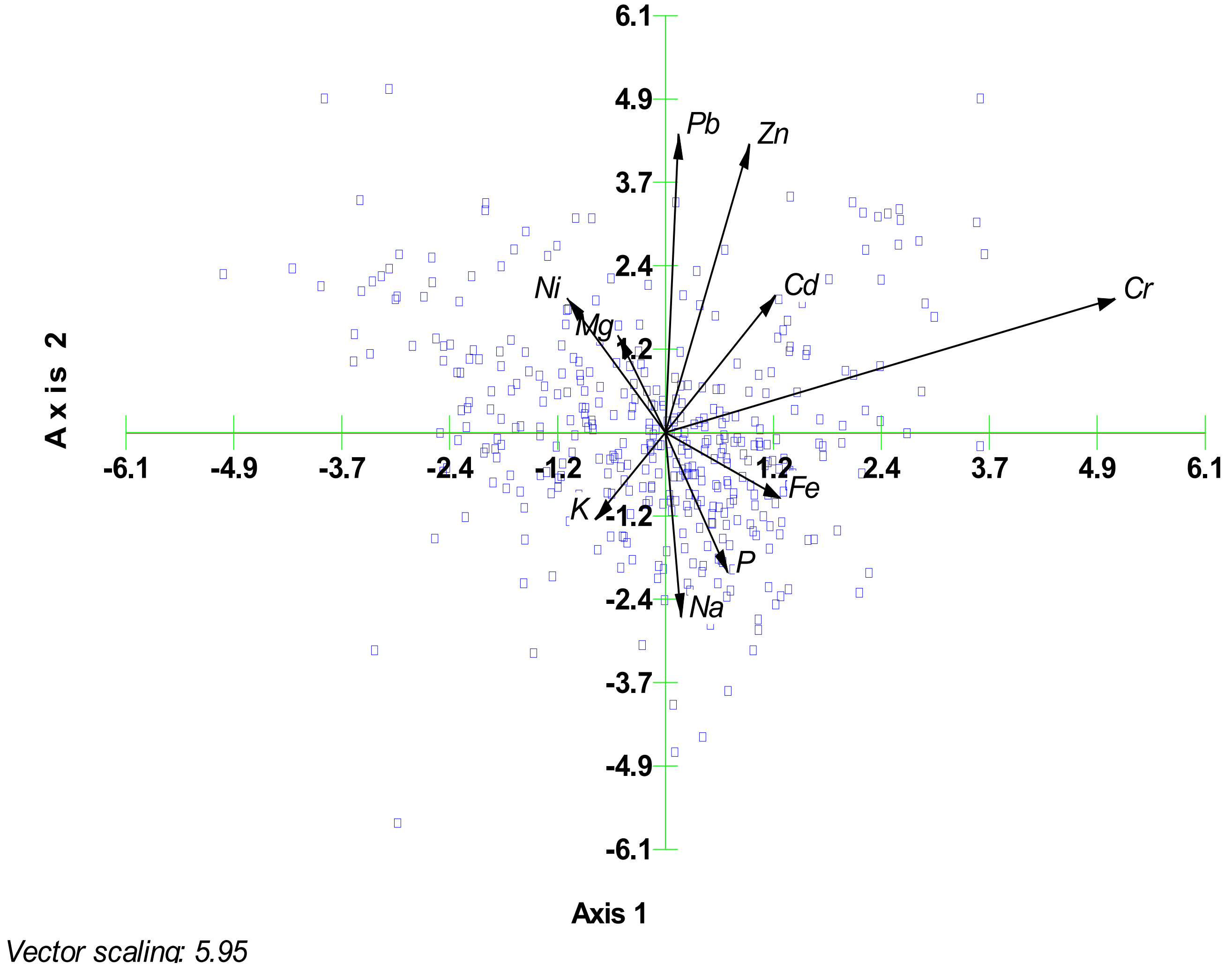

Fig. 2. CCA Biplot diagram of all roadside quadrats with different environmental variables.

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