Original Research

Environmental Factors Driving the Toxic Mobility between Soil and Vegetation in Riparian Zone Vegetation

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Abstract

The current study for vegetation analysis was carried out along the bank of river Chenab in District Gujrat, Pakistan. Ordination techniques, Canonical Correspondence Analysis (CCA), Detrended Correspondence Analysis (DCA) and TWINSPIN method were used to classify the herbaceous data. A multivariate analysis was employed to assess the connection between the herbaceous flora and environmental factors. Vegetation and soil samples were collected with geographical coordinates. The results revealed that all types of micro and macro nutrients, biotic and abiotic factors have the strongest influence in the existence of plant species and further these factors influenced the both major and minor groups of plant species. Simultaneously *Solanum nigrium* and *Chenopodium berlandieri* were found as the most abundant species. *Solanum nigrium* showed positive response in T-value towards soil moisture and chromium (Cr) while *Chenopodium berlandieri* showed negative response towards the lead (Pb). The spatial behavior of water quality was explained by an interpolation technique via Inverse Distance Weighted (IDW) to prepare thematic layer maps of all parameters for the Chenab River and this study also provided important information to preserve the herbaceous flora along the bank of Chenab river.

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Introduction

Ecological variables play a vital role in the development, management and reclamation of an ecosystem [1]. A large number of ecological researches shows the association between environment and vegetation cover [2-5]. Factors that affect the vegetation growth may include topography, climate, land use planning, natural resource exploitation, hydrologic conditions, and particularly soil characteristics [6-15]. Among different environmental factors, soil plays a vital role in the growth of plant. It is well-known that soil is a function of organisms, climate, time, topography, and parent material [16-17]. The association among soil properties and vegetation characteristics are complex at various stages in terms of vegetation heterogeneity and distribution of plant species. It is important to evaluate the relationships in order to understand various processes of an ecosystem [18, 19].

Among various rivers of Pakistan, the river Chenab has to irrigate a large adjacent area [20]. Punjab is the most populous province of Pakistan; it shares 59% of the gross domestic products and 76% agriculture production [21]. Gujrat is one of the leading Agri-rich, industrial and ecologically fertile Districts of the province Punjab. Due to the water resources and fertile land, it is considered as good land for cultivation [22].

The basic objective of this study was to use ordinal techniques for studying existing vegetation status and the effect of various soil characteristics on growing vegetation along Chenab river. Ordinal quantification employs disperse diagrams along 1 or 2 axis or uses points along axis [23]. The technique of ordinal quantification is used in phytosociology for the assessment of vegetation type and cover because of its key importance. Two Way Indicator Species Analysis (TWINSPAN) method was proposed for the classification of plant species and Detrended Correspondence Analysis (DCA) was used for clustering of closely related species as described by [24]; while Canonical Correspondence Analysis (CCA) was formulated for examining the correlation among plant species and environmental parameters [23].

Materials and Methods

Study Area

Gujrat is one of the leading agri-rich, industrial and ecologically fertile district of the province Punjab. Area of Gujrat is 3192 square kilometer having three tehsils Gujrat, Kharian and Sarai Alamgir. Gujrat has moderate temperature, as maximum temperature in summer has been reported as 45ºC and in winter it may fall below 2ºC. The average rain fall in Gujrat is 67 mm approximately [22]. Gujrat is present between two main rivers of Punjab, river Jhelum and river Chenab. This present study was carried along the bank of Chenab river as given in Fig. 1. Global Positioning System (GPS) device was used for the identification of coordinates along the bank of river, and marked out the points for herbaceous flora and soil data collection.

Data Collection and Chemical Analysis

Collection of herbaceous flora was done in the month of February and April. Total 40 quadrates 1x1 meter were laid during the present study.

Samples were carefully collected in sampling bags from the depth of 0 to 15 cm with spade and tagging was done from different areas especially those areas where definite change or mostly anthropogenic activities were involved. 10 samples were taken from different sites. In these soil samples soil texture, saturation, potassium, phosphorus, organic matter, electrical conductivity, pH and heavy metals like chromium (Cr), lead (Pb), arsenic (As), zinc (Zn), copper (Cu) and nickel (Ni) were checked as described by International Center for Agriculture Research in the Dry Areas (ICARDA) standard methods 2013. Soil samples were air dried and grounded with a wooden pestle, pebbles stones and lager debris were removed from the samples and further it was sieved with the help of 2mm sieve for analysis [25].

For chemical analysis, saturated paste percentage method was used to determine the soil texture [25] and Walkley-Black method was used for the calculation of organic matter [26]. pH was measured by pH meter with combine electrode and reference electrodes [25]. EC of soil sample was measured by conduit bridge method [25]. The innovative $CuSO_4.5H_2O$ technique formed and explained by Walkley et al. [27] was used for the phosphorous detection [28]. For potassium estimation flame photometer was used.

Data analysis

Complex datasets of GIS technique represent spatiotemporal variations, prevailing environmental
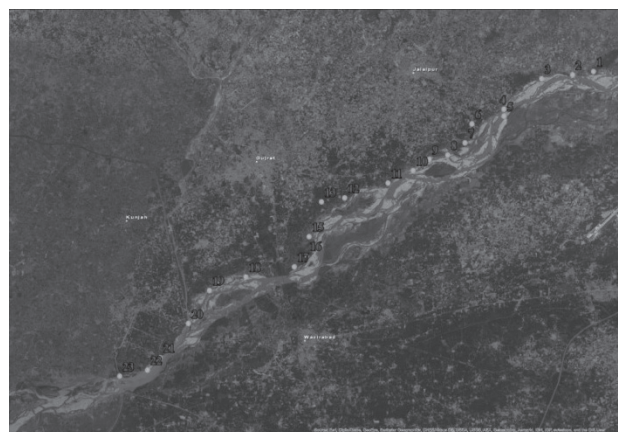

Fig. 1. Study Area and Sampling Sites.

conditions and climatic fluctuations of any ecosystem in a better way. The coordinate points in the form of point layer file were exported to ArcGIS software along with their analyzed results. Metadata of all the sample were put in the point attribute table after coding. The spatial analyst tool was used to describe the spatial behavior of soil quality. An interpolation technique along with Inverse Distance Weighted (IDW) was used to make thematic layer map of every constraint for the Chenab river [29].

The current study was used for the ordinal assessment of vegetation data for describing close relationship between various plant communities via indirect gradient analyses i.e. Detrended Correspondence Analysis (DCA). Relationship among herbaceous community and environmental data were examined via Canonical Correspondence Analysis.

In the present study, in order to classify standing plant species at the bank of river Chenab and for describing main communities on the basis of abundance and relative frequencies, Two Way Indicator Species Analysis (TWINSPAN) was used with the help of PCORD 5.1 [30].

Canonical Correspondence Analysis (CCA) or direct gradient analysis technique and its sub techniques of partial ordination and Van Dobben circles was applied to explain ecological relationship among soil and existing plant communities. CANOCO 4.5 software program was used to determine Detrended Correspondence Analysis and Canonical Correspondence Analysis [31]. Soil parameters including pH, organic matter, macronutrients, micronutrients and EC were measured for analyzing the effects of various soil characteristics on plant growth.

Results and Discussion

Results during the vegetation analysis were divided into three sections. Section one; the pattern of vegetation and grouping of different plants populations with the help of TWINSPAN and DECORANA. Section two; data diminution recorded or the overall plant species and their detailed results were described by the second section. Section three; described the relationship between various plant species and communities with different environmental factors collected with the help of Canonical Correspondence Analysis (CCA). Total 50 plants species having 24 families were identified in study area.

Two Way Species Indicator Analysis (TWINSPAN)

The term TWINSPAN (Two Way Species Indicator Analysis) is based on computer program and used to classify the herbaceous species and samples and used to make the two-way order tables. This table will describe the occurrence of different species in the samples of study area (Table 1). Hierarchal method of classification is the technique of classification that divides the species into categories on the basis of samples. The species of the study area were divided into three different communities. Some of the species were isolated from the communities but they were the part of main group.

In Fig. 2, the presence and absence of species was denoted by two different colures. Black color represents the presence of species and white color represent the absence of species in the samples on the base of cut levels and state community was named based on two most dominant species.

Dendogram was divided into two groups i.e., one major group and one minor group. Major group A contains 2 sub-groups A1a and A1b.

Group A1a consisted of *Coronopus didymus, Pistia stratiotes, Calotropis procera, Conyza Canadensis, Eichhornia crassipes, Solanum nigrium, Typha angustifolia* and *Chenopodium berlandieri*. *Eichhornia crassipes, Solanum nigrium* and *Chenopodium berlandieri* were dominant in this group, so the group was named as Eichhornia-Solanum- Chenopodium.

Group A1b consisted of *Parthenium hysterophorus, Euphorbia helioscopia, Cirsium arvense, Cynodon dactylon, Amaranthus viridis* and *Anagallis arvensis*. This group was dominated by *Parthenium hysterophorus* and *Cynodon dactylon,* so the group was named as Parthenium- Cynodon.

Another group was minor group B and was further sub divided into B-1a and B-1b.

Group B1a consisted of *Solanum xanthocarpum, Melilotus indica, Tamarisk, Ipomea carnea lsa.* This group was dominated by *Melilotus indica* and *Tamarisk,* so the group was named as Melilotus- Tamarisk

Group B1b consisted of *Solanum surattense, Calystegia hederacea* and *Osmunda rejeles.* This group was dominated by *Calystegia hederacea* and *Osmunda rejeles* so the group was named as Calystegia- Osmunda

Similar study was conducted by Khan et al. [24], to examine weeds data along Khanpur dam. Khan et al. [32] studied the ecological relationship of plants and environmental variables using TWINSPAN software of natural resources in Soon Valley, Khusab. In 2018, Zia et al. [33] used the same technique to study vegetation of district Narowal. The road side vegetation's of Wah Cantonment was analyzed by Lu and Wong, [30] by using TWINSPAN.

Dominance Curve

Fig. 3 was formulated to identify the dominance of the species in study area by formulating the rank. In this study the graph was developed using the rank of abundance in opposition to log sum values, species were plotted on the graph according to their dominance over the study area. This is scatter plot graph and it showed the most abundant species was *Anagallis arvensis, Cynodon dactylon* was second and the third was *Amaranthus viridis*. The other dominant species, of

Table 1. Identification of Species and Their Families along Chenab River.

No.	Scientific Name	Family	No.	Scientific Name	Family
01	*Coronopus didymus*	Brassicaceae	02	*Pistia stratiotes*	Araceae
03	*Calotropis procera*	Apocynaceae	04	*Eichhornia crassipes*	Pontederiaceae
05	*Cynodon dactylon*	Poaceae	06	*Solanum xanthocarpum*	Solanaceae
07	*Parthenium hysterophorus*	Asteraceae	08	*Solanum surattense*	Solanaceae
09	*Conyza canadensis*	Asteraceae	10	*Melilotus indica*	Fabaceae
11	*Osmunda rejeles*	*Osmunda*	12	*Amaranthus viridis*	Amaranthaceae
13	*Solanum nigrium*	Solanaceae	14	*Tamarisk*	Tamaricaceae
15	*Euphorbia helioscopia*	Euphorbiaceae	16	*Calystegia hederacea*	Convolvulaceae
17	*Chenopodium berlandieri*	Amaranthaceae	18	*Anagallis arvensis*	Primulaceae
19	*Achyranthes aspera*	Amaranthaceae	20	*Cannabis sativa*	Cannabaceae
21	*Silybum marianum*	Asteraceae	22	*Arctium tomentosum*	Asteraceae
23	*Malva parviflora*	Malvaceae	24	*Xanthium spinosum*	Asteraceae
25	*Datura stramonium*	Solanaceae	26	*Asphodelus tenuifolius*	Xanthorrhoeaceae
27	*Carthamus oxyacantha*	Asteraceae	28	*Cirsium arvense*	Asteraceae
29	*Xanthium strumarium*	Asteraceae	30	*Typha angustifolia*	Typhaceae
31	*Verbascum thapsus*	Scrophulariaceae	32	*Avena fatua*	Poaceae
33	*Phalaris minor*	Poaceae	34	*Sisymbrium irio*	Brassicaceae
35	*Ipomea carnea lsa*	Convolvulaceae	36	*Medicago littoralis*	Fabaceae
37	*Vicia sativa*	Fabaceae	38	*Tribulus terrestris*	Zygophyllaceae
39	*Poa annua*	Poaceae	40	*Lathyrus aphaca*	Fabaceae
41	*Setaria viridis*	Poaceae	42	*Justicia adhatoda*	Acanthaceae
43	*Chrozophora tinctoria*	Uphorbiaceae	44	*Eclipta*	Asteraceae
45	*Cichorium intybus*	Asteraceae	46	*Artemisia scoparia*	Asteraceae
47	*Saccharum spontaneum*	Poaceae	48	*Polygonum monspeliensis*	Polygonaceae
49	*Eleusine indica*	Poaceae	50	*Dichanthium annulatum*	Poaceae

the study area was observed from the dominance curve shown in the Fig. 3.

Canonical Correspondence Analysis (CCA)

Multivariate analysis was the most adaptable technique. The ordinate space for CCA analysis and dispersion of species in analysis were same as the DCA. This was the direct analysis technique and environmental gradients and the response of species were noticed by using different techniques and application of CCA analysis. There were different variables used for the species and variables of soil that were co- related with soil moisture, pH, EC, P, K, As, Ni, Cr, Pb and Cu. The triangle signified the single species whereas the arrow head identified the environmental species. Maximum change of environmental factors was signified by the points on the diagram. Length of the arrow also represented the maximum change and their magnitude was proportional to the change in the environmental variables. Larger the length more the impact and influence on the single species so EC, OM, Pb and Ni had the longest length of arrow head because these factors showed strongest influence on the growth of species. Due to this reason, only *Parthenium hysterophorus* was able to show the correspondences towards OM, *Coronopus didymus* towards Cr, K and P have same lengths of arrows heads. In the case of saturation, there was no species around the arrow however Zn have the smallest length of arrow but *Cynodon dactylon* showed the correspondence towards Zn. The species that were away from the environmental arrow heads were free from the influence of the environmental gradients as shown in Fig 4.
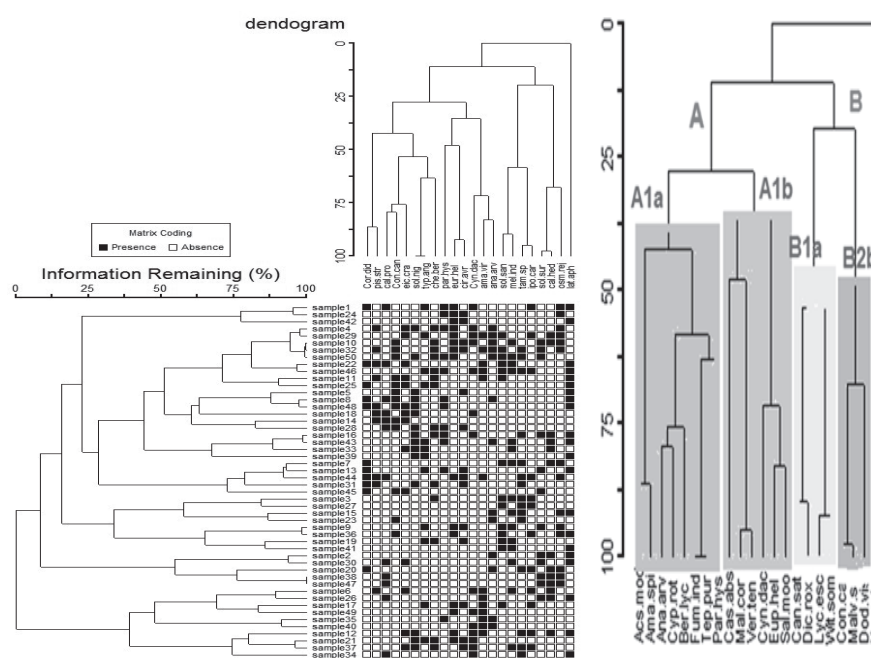
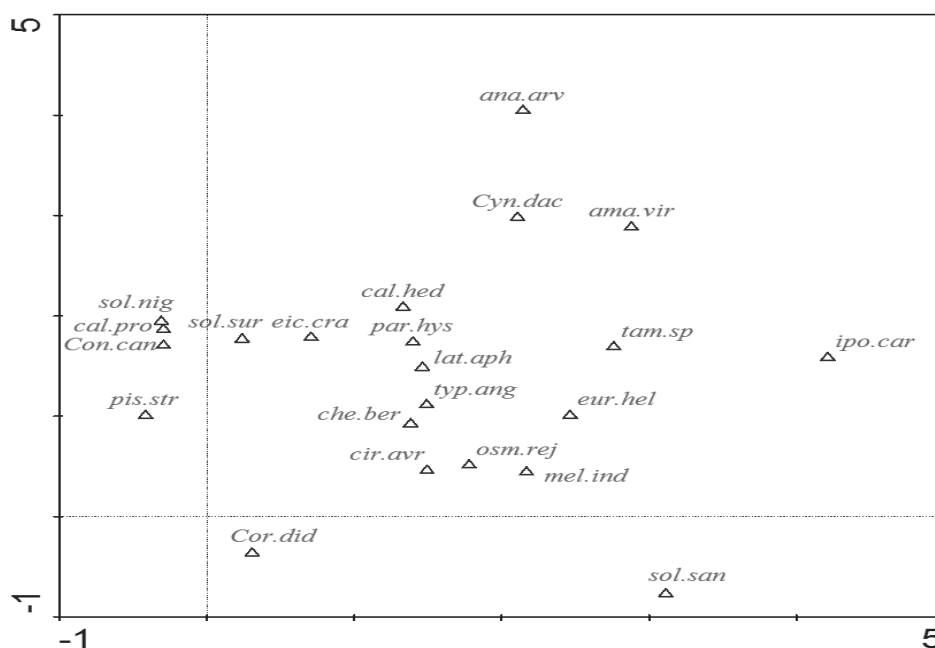Fig. 2. Two Way Species Indicator Analysis delineated groups and communities.

Fig. 3. Dominance Curve: The scatter plot graph showed the most abundant species.

T-value Biplot

T-value biplot is the statistical technique used as tool to produce the special kind of bioplots in this Van Dobben circles were formed that explained the response of different species towards environmental variables (soil moisture, pH, EC, P, K, As, Ni, Cr, Pb and Cu). Arrow heads represent the species while triangle symbol represent the environmental variables. Species with the arrows in the same circle represents the T-value statistics $^+2$ or $^-2$. The environmental points are shown outside the interval thus showing T-value was greater than $^+2$.

The T-value Biplot represented the association between the soil organic matter (OM) and different vegetation species present in the study area. This parameter had the strong impact on the growth but
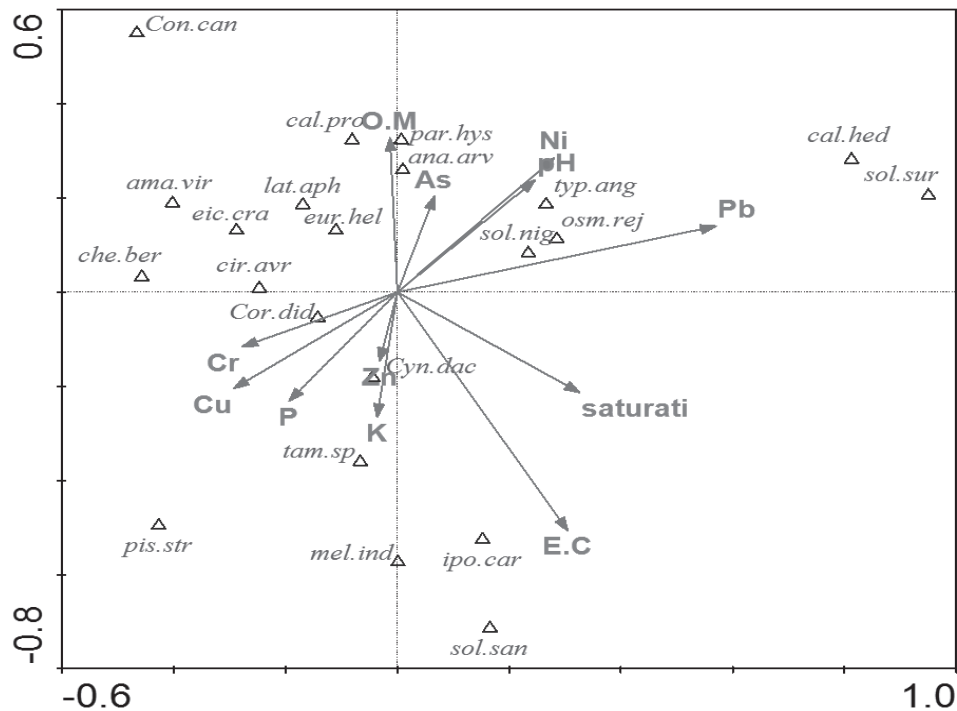
Fig. 4. Canonical Correspondence Analyses (CCA): The triangle signified the single species whereas the arrow head identified the environmental species. Length of the arrow represented the maximum change and their magnitude was proportional to the change in the environmental variables.

species growth was also influenced by the presence and absence of the OM. As *Calotropis procera, Anagallis arvensis, Parthenium hysterophorus, Calystegia hederacea* and *Euphorbia helioscopia* showed positive response while *Coronopus didymus, Pistia stratiotes and Cynodon dactylon* showed negative response related to the T-value Biplots. Mostly species shows positive response that OM has influence on plant species.

Electrical conductivity (EC) was also prominent factor in the growth of vegetation. Dobben circles expressed the positive and negative response of species towards EC. Red circle showed positive response while blue circle showed negative response. *Solanum xanthocarpum* showed the strongest positive response. Other species showed positive response for EC were *Melilotus indica, Cynodon dactylon, Ipomea carnea lsa, Pistia stratiotes* and *Tamarisk*. While *Conyza canadensis* showed strongest negative response for EC. Furthermore, the species passing through blue circle also showed negative response towards EC.

T-Value for soil moisture/ saturation represented the relationship between the soil moisture and vegetation of study area. No species was strongly affected by the saturation of soil but few species showed positive response and those species were *Solanum xanthocarpum, Solanum surattense, Solanum nigrium, Tamarisk* and *Pistia stratiotes*. However, few other species were also passed through the red circle. *Conyza canadensis* showed strongest negative response and

species passing through blue circle showed negative response. Other species have less influence of soil moisture on growth.

T-value for the Potassium (K) showed that *Pistia stratiotes* was positively influenced by the K and *Calystegia hederacea* and *Solanum surattense* showed negative response because they were not influenced by the presence or absence of K in the soil. While other species passed through the circles are not much influenced by the K content.

Phosphorous (P) is also an important constituent for the plant growth. T -value of P also showed the relationship between the available P and growth of vegetation. Species *Solanum xanthocarpum, Melilotus indica, Ipomea carnea lsa* and *Tamarisk* showed positive responses' while *Calystegia hederacea* showed the strongest negative response.

T-value for the Pb presented that some species showed strongest positive and strongest negative response. *Solanum surattense* and *Calystegia hederacea* showed the strongest positive response and *Chenopodium berlandieri* and *Cirsium arvense* showed negative response. Other species were slightly influenced by the presence of Pb.

The T-value projects the linkage between the As and different plant species found in the study locale. The soil parameters have direct impact on the flora growth however these species have positive or negative response was linked with presence/ absence and concentration of environmental variables. Here, in the present study,
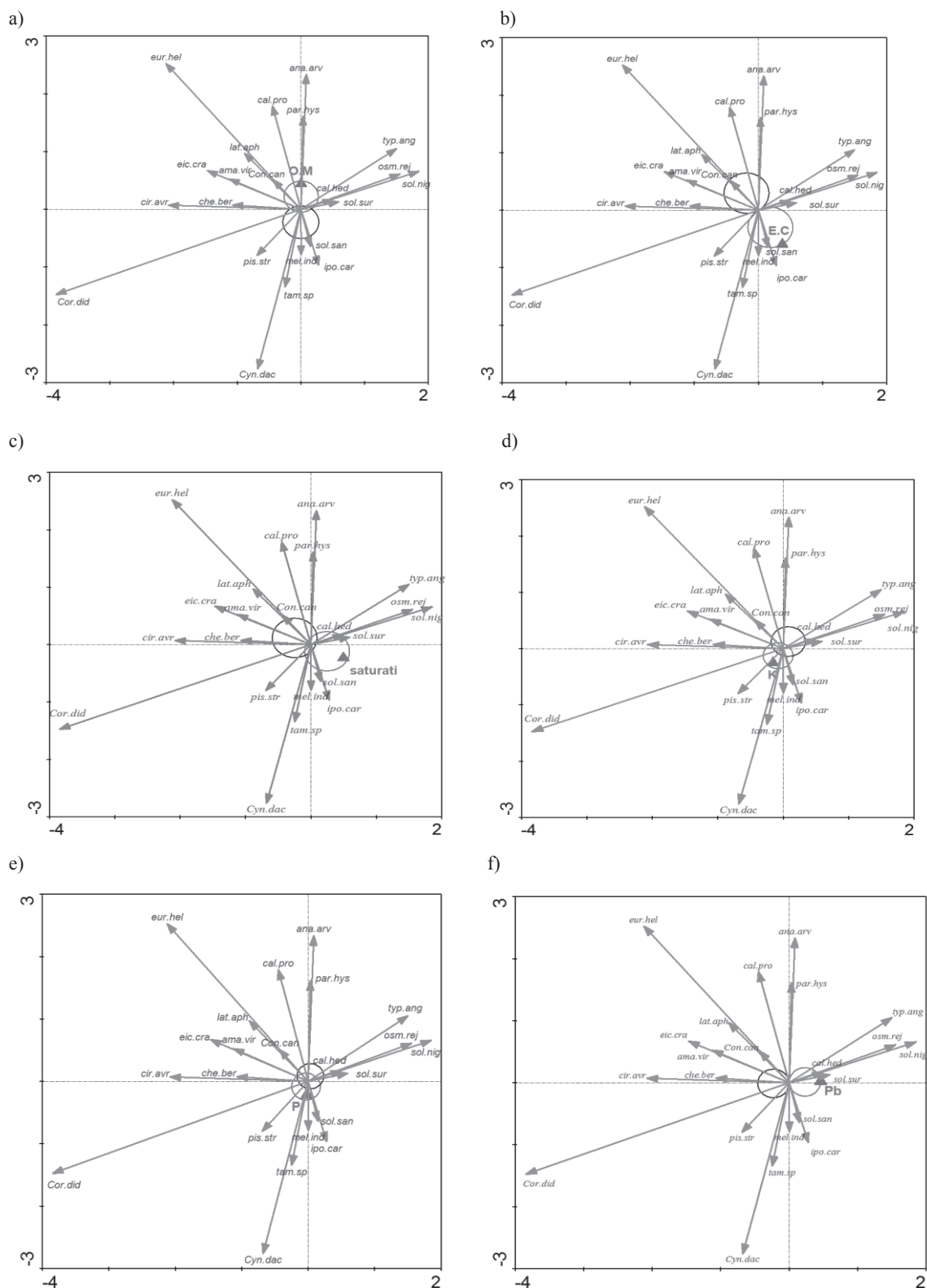
Fig. 5 a) T-value Biplot for Soil, b) T-value Biplot for EC Organic Matter, c) T-Value Biplot for Soil Moisture, d) T-Value Biplot for Potassium, e) T-Value Biplot for phosphorous, f) T-Value Biplot for lead (Pb), g) T-Value Biplot for Arsenic (As), h) T-Value Biplot for Chromium (Cr), i) T-Value Biplot for Copper (Cu), j) T-Value Biplot for Nickel (Ni). Arrow heads represent the species while triangle symbol represent the environmental variables. Species with the arrows in the same circle represents the T-value statistics ⁺2 or ⁻2. The environmental points are shown outside the interval thus showing T-value was greater than ⁺2.
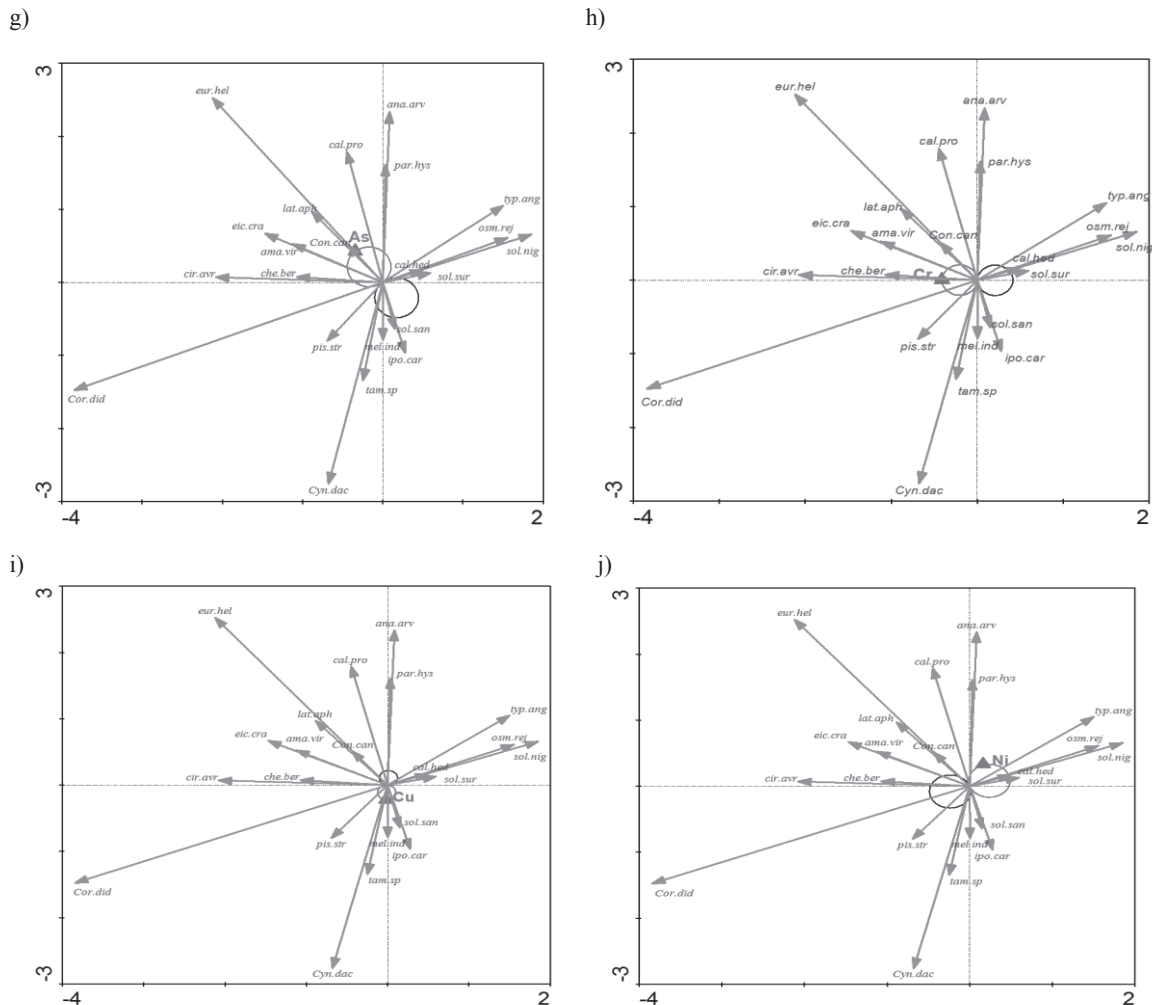
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Fig. 5(a-j). Continued.

the species *Conyza canadensis* and *Lathyrus aphaca* showed positive response along with other species passed through red circle. *Ipomea carnea lsa, Melilotus indica* and *Solanum xanthocarpum* showed negative response towards presence or absence of As.

The T-value regarding available Cr also depicted that *Chenopodium berlandieri* and *Cirsium arvense* showed positive response while *Solanum surattense* and *Calystegia hederacea* showed the strongest negative response. Most of the lines of plant species were passed through red circle which shows that these species showed positive response towards environmental variables.

The vegetation species were represented by arrow head and Dobben circles with help of colures that determined the positive and negative responses. T-value Biplot for flora represents that *Solanum xanthocarpum, Melilotus indica* and *Ipomea carnea lsa* were closed to the environmental variable and showed stronger positive response related to other species passed through red circle. While species like *Parthenium hysterophorus* passing from blue circle showed negative response against Cu.

The T-value Biplot diagram regarding available Ni presented that no species showed strongest response while *Calystegia hederacea* and *Solanum surattense* showed positive response. However, most of species were passed through negative circle and *Pistia stratiotes* showed strongest negative response against Ni.

Pie Symbol Plot

In the present study every environmental variable was divided into different classes according to the number of samples using different symbols. The space of symbols tells the relative abundance in each plot. The current study gave the results of absence or presence of plant species in these classes.

Species were divided into four classes. Pie chart for pH was ranged from 7.0-7.8 with average value of 7.49. Class 1 contained 20 members while others three classes contained 10 members each however the dominant class contained most of the vegetation samples.

In the case of OM, the environmental variables were divided into four classes with range from 0.2 to 0.67 and has the average value of 0.291. The species
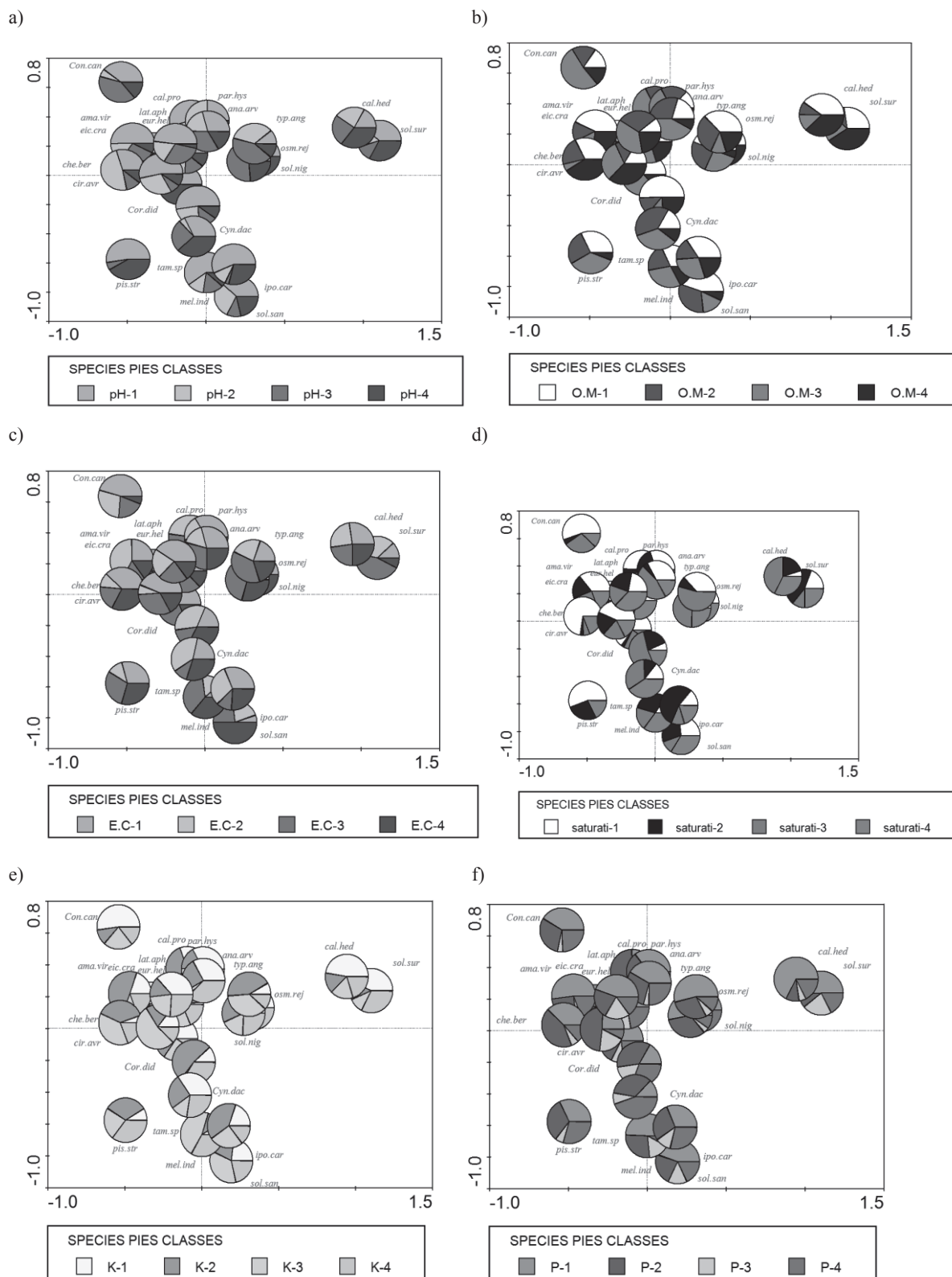
a)

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Fig. 6 a) Soil pH pie Symbol Plot, b) Soil Organic Matter pie Symbol Plot, c) Soil Electrical Conductivity, d) Soil moisture Pie Symbol Plant Pie Symbol Plot, e) Available Potassium Pie Symbol Plot, f) Available Phosphorus Pie Symbol Plot,. g) Lead Pie Symbol Plot, h) Arsenic Pie Symbol Plot, i) Chromium Pie Symbol Plot, j) Copper Pie Symbol Plot, k) Nickel Pie Symbol Plot, l) Zinc Pie Symbol Plot. Environmental variables were divided into different classes according to the number of samples using different symbols. The space of symbols tells the relative abundance in each plot. This figure gave the results of absence or presence of plant species in these classes.
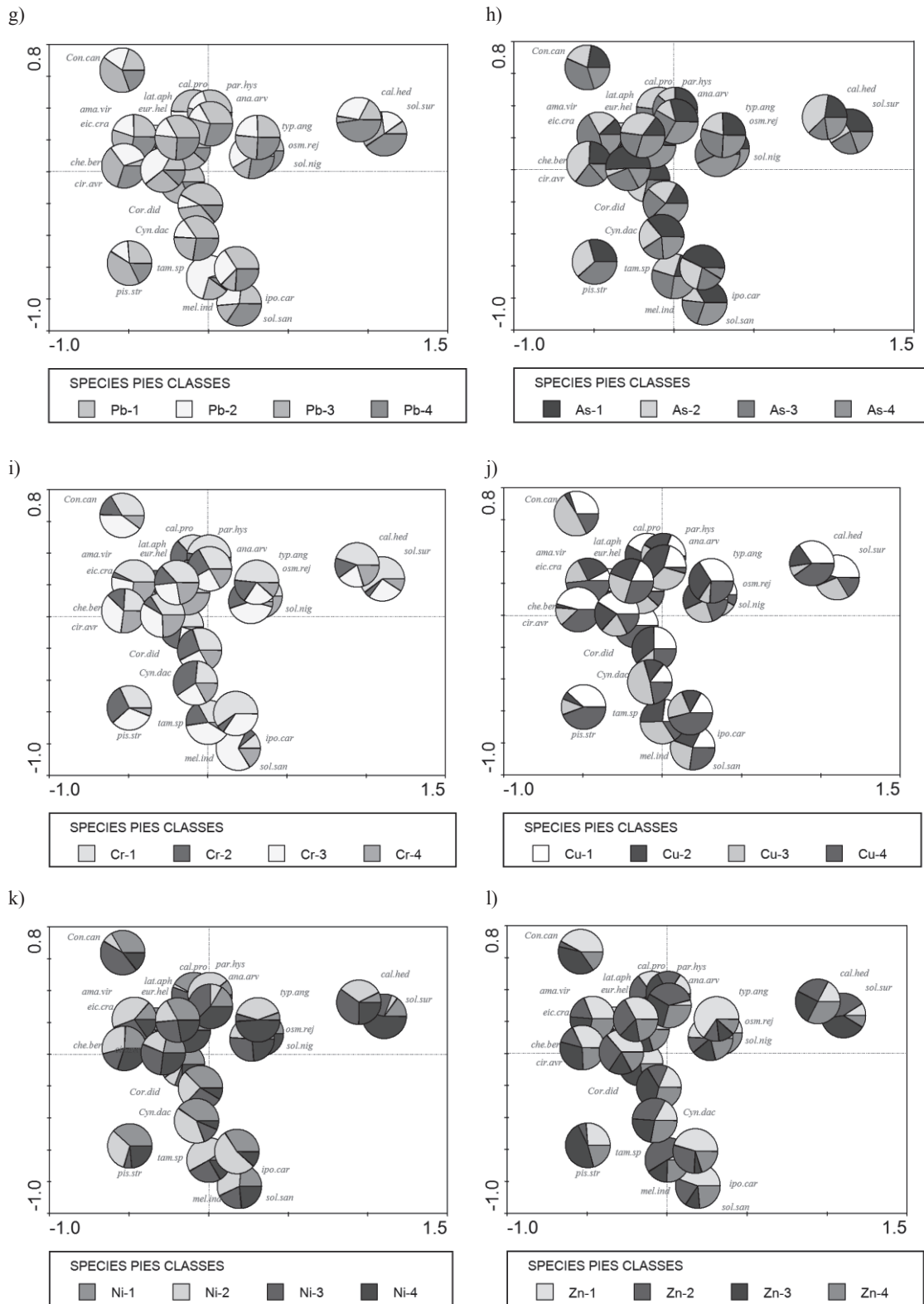
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Fig. 6(a-l). Continued.

were distributed as 15, 10, 14 and 11 members in four classes respectively. Majority of the plants were shown in every class but most of the species favored class 1. The OM richness between these quadrates lies between 0.51-0.71.

EC was also an important factor in the growth of vegetation species in the study area. It also showed strong impact of presence and abundance of species in the Fig. 4 that showed EC of the soil was divided into four classes having 13, 12, 13, 12 members respectively

with class 1 having maximum richness. The EC was recorded in the range of 0.95 to 1.94 with average value of 1.404.

Soil moisture was the component for survival of species in the study area. The soil moisture content was observed in the range from 32 to 60 with average value of the 42.4. The moisture content was divided into four classes where class 1 contained 15, class 2 contained 10, class 3 contained 13 and class 4 contained 12 members.

The range of K was measured in the range of 61 to 163 with average value of 88.5. The species were divided into 4 classes; class 1 & 2 contained 13 while class 3 & 4 contained 12 members each however the class 1 was dominant class.

Phosphorus (P) was also divided into four classes and its range started from 3 to 8 and it showed the average value of 4.3. In the results, class 1 have 20 members, class 2 have 14, class 3 have 6 and class 4 have 10 members. However, the class 1 & 2 showed richness in diversities of species.

The range of Pb was found between -0.2 to 3.24 with average value of 2.057. Species were divided into 4 classes contained different members such as class 1 and 3 contained 13 members while class 2 and 4 contained 12 members each however class 4 contained best species richness.

Arsenic (As) is also an important component for survival of vegetation species in the study area. The range of the As started form the -5 to 10 with the average value of 6. Species were divided in to four classes where class 1 and 3 contained 13 members while class 2 and 4 contained 12 members. Class 4 supported growth of maximum species.

The range of Cr was found between 0.015 to 0.1 with the average value of 0.0559. Species were divided into 4 classes with class 1 having 18, class 2 having 8, class 3 having 16 and class 4 having 8 members. Class 1 showed maximum richness in diversities of species.

The range of Cu started from 1.98 to 3.25 and have average value of 2. Species were divided into 4 classes with class 1 containing 14 members, class 2 containing 11 members, class 3 containing 13 members and class 4 containing 12 members. Class 3 showed higher species richness.

Environmental variable Ni was also divided into four classes. Its range was found between 1.68 to 1.12 and has the average value of 1.2. The species were distributed as 13, 14, 11 and 12 members in four classes respectively. Majority of the plants were showed in every class but class 2 showed prominent richness.

Zn was found in the range between -1.6 to 0.01 with the average value of -0.0423. The species were distributed as 14, 11, 13 and 12 members in four classes respectively. The majority of the plants were showed in each class however the class 1 was with prominent richness as shown in Fig. 6l).

Chenab river was very rich in vegetation along with different flora types while doing survey about 60 different types of herbaceous flora are collected from study site village Dhool to Head khanki. Vegetation data was monitored by the ordination techniques by using method of TWINSPIN, CCA and DCA. Some the species were isolated from the communities but they were the part of main group. Zereen et al. [34] studied T-value bi-plots and applied the effect of altitude on vegetation growth. Species that were positively correlated with altitude passed through red circle while those whose growth was suppressed by altitude were passed through blue circle.

In the study area of river Chenab, plants species were divided into major groups A and minor group B. Group A was further divided into subgroups A1a contained dominant group *Eichhornia-Solanum-Chenopodium* and A1b contained *Parthenium- Cynodon* dominant group. Minor group B was also divided into B1a had dominant group *Melilotus- Tamarisk* and B1b had *Calystegia- Osmunda. Eichhornia crassipes, Solanum nigrium* and *Chenopodium berlandieri* were most abundant species. All types of nutrients' including micro and macro nutrients, biotic and abiotic factors had the strongest influence in the existence of plant species and they were influencing both major and minor groups. Partial ordination had estimated the probability of the effects of environmental parameters in community structures at different range level for same variable [35]. In a similar study Zia et al. [33] investigated the relationship between plant distribution and ecological factors of district Narowal, Pakistan and described the importance of vegetation cover for preventing soil erosion and providing food and habitat for wild life. Moreover, a study conducted by Khan et al. [32] reported the correlation of wet land complex of Soon valley of Pakistan.

Conclusion

The results of the present study concluded that the growth of plants was under the influence of various soil properties including soil nutrients, soil inorganic ions, and soil physical property however their effects were according to the sample locality. Keeping in view the current scenario and result the current vegetation cover along Chenab river in Gujrat Pakistan is facing many troubles due to straight flooding, agricultural practices, over grazing, soil erosion, deforestation and expansion like construction, industrial development responsible for the change in environmental variables.

Acknowledgement

Conflict of Interest

The authors declare no conflict of interest.

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