Scaling of spatial variation in ground flora of Tharparker, Pakistan

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Abstract

The role of vegetation is very important in ecosystem conservation. The present study was conducted to classify the existing ground flora in Tharparker, Pakistan. The distribution pattern of vegetation and species association was grouped into different communities by using ordination techniques. Both direct and indirect ordination methods were applied to classify the species into groups and communities, and also quantify the relationship of species with varied soil parameters (pH, EC, moisture, OM, K, P, Fe⁺³, Zn⁺², Mn⁺², Cu⁺²). Plant and soil samples were randomly collected using quadrat of 1 * 1 m². Two main groups and four communities were formed by species derived from fifty quadrat. *Cynodon dactylon* and *Desmostachya bipinnata* showed higher abundance over the broad range of all edaphic factor's concentration. This study provided the significant results of least abundant and most abundant herbaceous species in the region of Tharparker, which will be helpful for land managing and planning.

Keywords Ecological model · Herbaceous plants · Multivariate · Ordinal classification

1 Introduction

In ecology, plant distribution and relationship of plant species with environmental gradient is significantly important, because it reflects the pattern of species abundance and diversity [1]. Studying the relationship of species with environmental parameter and classification not only is important in the research field of ecology, but also gets difficult for analyzing the community structure. Complexity of interaction between plants and abiotic factors is a major constraint for predicting plant response to environmental changes. However, vegetation response and future scenario can be predicted by computer models. Computer simulation is dependant on accurate data set of parameters and not limited by time and space which is hurdle in experimentation. In the case of conservation and management practices, classification is very important which depends upon the scale of measurement. In this perspective, multivariate techniques are very useful in ecology [2]. For the identification of association within species on the

basis of abundance and vegetation composition, two-way indicator species analysis (TWINSPAN) technique is widely applied by ecologist.

Existence and abundance of different plant species depend upon the spatial variability within the area. Plants show different growth responses to spatially distributed edaphic factors like the presence of moisture, macronutrients and micronutrients.

Many researches have shown the importance of direct and indirect ordination techniques of multivariate. Likewise, the relationship between environmental parameter and plant species along distribution pattern in Chott El Beida (RAMSAR protect wetland) situated in Algeria was studied using TWINSPAN, and 127 species of 41 families were identified within four communities [3]. This study improved the baseline record of vegetation community. In Pakistan, different studies based on ordination techniques have been carried out. Likewise, Khan et al. [4] studied the vegetation and distribution pattern in semiarid area of Pakistan using ordination techniques.

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Urooj et al. [5] investigated the relationship between the plant growth and environmental parameters and showed the generalized linear model of species growth response at a varied range of physical and chemical parameters. Using these techniques, distribution pattern, abundance, types of species and influence of physical environmental factors on species can be studied and investigated. In another study, vegetation of 40 quadrats was classified into communities using TWINSpan [6].

In the present study, an effort has been made to analyze and explore the correlation of plant communities with edaphic factors. Desert is extremely dry areas supporting sparse distinctive vegetation including mostly shrubs and herbs specially adapted to the harsh environment.

The objectives of the present study were to classify the existing herbaceous flora of the ecologically important arid region (Tharparker) during wet season and to analyze the effect of soil parameters on the growth of herbaceous flora using ordination technique.

2 Materials and methods

2.1 Study area

Tharparker is located between 24.159° and 25.7° N latitude and 69.059° and 71.2426° E longitude and is the largest district land area of Sindh province. Land is mostly deserted and consists of rainfed vegetation. Rainfall only occurs in the months of June, July and August [7]. Land of Tharparker depicted a classic green view during the period of sufficient rainfall, like in the period of monsoon. Tharparker district has tropical desert climate which is hot during the summer and coldest in winter. However, annual rainfall is recorded as low as 100 mm which fluctuated more often and maximum precipitation is recorded during the monsoon season. Saand et al. [7] reported dominant vegetation in Tharparker belongs to Poaceae and Fabaceae families. About 60% species are herbaceous, and 40% are reported as shrub. Mostly trees and shrubs are on farmland and come under the property right of inhabitant, and the only prohibited thing is that nobody is allowed to cut any tree from farmland, but herbs and grasses that grow on rangeland are more prone to threat [7]. The community structure and plant distribution pattern of Tharparker region are poorly understood and have not been given by plant ecologist till the date.

2.2 Data and methodology

During growing season (July–September), plants were collected along with soil samples using $1 \times 1 \text{ m}^2$ quadrat in the year 2018. Total 50 quadrats were laid down, and Domin

cover scale was used to estimate the cover value of each species from each quadrat [5]. Soil samples were randomly collected along vegetation from each quadrat at depth of 6–12 cm. Vegetation classification was carried out using the technique of TWINSpan via software PCORD which indicated the abundance of each species in each quadrat. DCA was applied as another indirect ordination technique for the verification of TWINSpan results [8–12]. Moreover, dominance curve was also created between log values of sum abundance and rank of abundance which described the ranks of species on their abundance/frequency of the existence in the study area. For the assessment of the relationship between species and available soil parameters, a direct ordination technique named CCA was applied using the Canoco 4.5 version [13]. Soil parameters included pH, EC, organic matter, potassium, phosphorous, moisture, zinc, copper, ferrous and manganese. Soil samples were analyzed for soil pH and EC by preparing soil extract solution in 1:2 ratio [14], and soil organic matter was calculated by following the procedure of Nathan and Gelderman [15]. Samples were dried, pulverized and sieved by using 2-mm-size sieve for all chemical analyses except soil moisture and organic matter. Method of Nathan and Gelderman [15] was followed for analyzing macronutrients (P and K) which are essential for plant growth. Method of acid digestion using aqua regia (containing 3:1 ratio of HCl and HNO_3) given by Ehi-Eromosel et al. [16] was applied for analyzing the micronutrients on atomic absorption spectrophotometer. Generalized additive model (GAM) as modern regression method was applied to provide the correct interpretation of ordination [17]. Species response model-based ordination is the best to interpret the change of species response along the ordination axes. In the present study, generalized additive model (GAM) was applied based on the following equation of linear model [18].

$$Y = EY + e \quad (1)$$

$$\text{And } EY = f(X_1, \dots, X_p) \quad (2)$$

where Y is the response variable, EY is the response variable expected for predictor and e is the variability of true value around the expected value EY . $X_1 - X_p$ are predictor values. In Eq. (1), EY is the systematic component, and e is the stochastic component of regression model.

However, GAM extends the general linear model in two ways: Firstly, EY is not supposed to be always directly equal to the linear combination of the $X_1 - X_p$. Instead, scale of predictor determines the scale of response variables using parametric function known as link function given in Eq. 3; secondly, GLM has less specific assumptions about the stochastic component as compared to the general linear models [19].

$$g(EY) = \eta \quad (3)$$

$$\eta = \beta_0 + \beta_j X_j \quad (4)$$

where η is the linear predictor.

2.3 Results and discussion

In total, 21 species were identified that belong to 6 families. Species were classified using TWINSpan technique, which divides the percentage cover scale into six groups using five cut levels. This indicated the occurrence of species in particular quadrats. The hierarchy of classified species is shown by species dendrogram in Fig. 1, which represents two main groups A and B. Group A indicated only one species, i.e., *Cynodon dactylon* (Poaceae), whereas Group B was divided into four communities presented with different colors, showing community of associated species against similar habitat conditions in the area.

Community I under the group B comprised of eight species, i.e., *Ochthochloa compressa* (Poaceae), *Cenchrus setigerus* (Gramineae), *Panicum antidotale* (Poaceae), *Dichanthium annulatum* (Poaceae), *Sporobolus marginatus* (Poaceae), *Typha species* (Typhaceae), *Orghum halepense* (Poaceae) and *Tribulus terrestris* (Zygophyllaceae). On the basis of dominant species (*Typha species*, *Sorghum halepense*), this community was given a name Typ-Sor. Similarly, community II was named as Cit-Phr due to the *Phragmites species* (Poaceae), the *Citrullus colocynthis* (Cucurbitaceae) being the dominant species. Besides, total four species were enlisted in community II. *Panicum turgidum* (Poaceae) and *Saccharum spontaneum* (Poaceae) were the other than two dominant species in this community. *Cenchrus ciliaris* (Poaceae) and *Lasiurus scindicus* (Poaceae) were the dominant species in the community III and named as Las-Cen. This community also comprised *Cenchrus biflorus* (Poaceae) species. The community IV was

classified on the basis of five species and named as Des-Cal on the abundance of *Desmostachya bipinnata* (Poaceae) and *Calligonum polygonoides* (Polygonaceae) species along the other three more species, i.e., *Eragrostis species* (Poaceae), *Eragropagan species* and *Dactyloctenium scindicum* (Poaceae).

Figure 2 shows the curve between the log sum and rank abundance which indicated the abundance of each species at unit time in the study area. This presented the status of *C. dactylon* as the most frequent species and placed this in the first rank in the curve. *D. bipinnata* showed the second and *S. halepense* was placed in the third rank followed by *C. dactylon*. Two species *T. terrestris* and *P. turgidum* were present at the lower rank due to the lesser abundance shown by the log value of sum abundance, i.e., 0.698.

Results of TWINSpan were verified and supported with another ordination technique named as detrended correspondence analysis (DCA) shown in Fig. 3.

Results of DCA presented community of *Ochthochloa Compressa*, *Panicum antidotale*, *Tribulus terrestris* and *Dichanthium annulatum*, *Typha species*, shown in

Fig. 2 Dominance curve

Fig. 1 Two-way cluster analysis of Tharparker plant species

Fig. 3 DCA scatter plot

dendrogram. Similarly, *Phragmites species*, *Panicum turgidum* and *Saccharum spontaneum* were shown as associated species as revealed by the community II in Fig. 1.

Results of analytical test of soil samples showed the varied concentrations of micronutrients (zinc, copper, ferrous and manganese) and macronutrients (P and K) up to greater levels along with other parameters, i.e., pH, EC, moisture and organic matter. The range of analyzed pH and EC of soil samples was 7.4–7.8 and 0.8–1.4, respectively, in the soil samples. 0.9–1.8% organic content was found along with 20–41% moisture.

Figure 4 shows the T-value biplot which indicated the positive and negative correlations of all identified species with all analyzed edaphic factors. Arrowheads and length show the response of species to the selected environmental variable. Likewise, in Fig. 4 results of direct ordination technique showed the influence on the growth of *O. compressa*, *C. dactylon*, *S. spontaneum*, *P. turgidum*, *P. species*, *D. bipinnata*, *C. biflorus*, *C. ciliaris* and *E. species* by macronutrients (potassium) and micronutrients (copper and zinc). All other identified species had no significant effect of Fe^{+3} and Mn^{+2} on growth and abundance.

Results showed the assumptions about the variables and predictors in Figs. 5 and 6. The assumed relation between stochastic and systematic components indicated the Gaussian reference distribution of response variable on the scale of predictor. It was found that *D. bipinnata* grown over the wide range of pH, EC, potassium and phosphorus. Most abundant species was *Cynodon dactylon* which showed higher growth, but did not revealed the equal distribution over the found range of physiochemical properties of soil. Likewise, with increasing pH, growth of *C. dactylon* was also increasing. Similarly, abundance of *C. dactylon* was found at higher concentration of potassium. Different species showed different responses at different concentrations of micronutrients (Zn, Mg, Fe and

Cu). Concentration range of copper (1.28–1.66 ppm) in study area soil was found most suitable for the growth of all identified species shown in Fig. 6a. Comparatively, the determined range of iron concentration (3.3–4.8 ppm) in soil depicted that the lower concentration supports the higher growth of *S. spontaneum*. *C. setigerus* showed the higher growth at higher concentration of manganese, and *C. dactylon* showed the abundance at both the lower and higher manganese concentrations (Fig. 6c). *D. bipinnata* showed equal distribution at 3.1–4.6 ppm. *D. bipinnata* was most abundant and dispersed species at the zinc concentration ranging from 0.5 to 0.9 ppm (Fig. 6d). At the same concentration range, the growth of *S. spontaneum* was also found well distributed in the study area.

Different ecologists have employed the technique of multivariate for the analysis of vegetation to describe the species frequency or abundance on the basis and response to variable environmental gradients [20]. A study was carried on plant classification using TWINSpan methods and the 22 species belonging to 10 families were identified. Researchers also indicated the significant role of micro- and macronutrients in species growth response toward the environment [21].

Similar study on the same method was conducted in Ayubia National Park, which imparts an important role in conservation and protection of native flora. In this study total 59 species belong to 32 families were classified and two communities were identified comprised of *Herd nepalensis*, *Plantago major* and *Rumex nepalensis* [22].

Results revealed that the *C. dactylon* and *D. bipinnata* were found as the most abundant species in the Tharparker and considered as environmentally friendly species. It is also used as low-cost feedstock for animals.

One reason for *C. dactylon* abundance is could be the long-distance dispersal of its pollen by the wind in large amount [23]. Besides, this species also has unique morphology because it only requires 13 h to grow at 6.3–6.8 optimum pH of soil. So another factor for its abundance is the prevailing condition and adaptive nature of *C. dactylon* in a wide range of climates and did not show the dormancy in any season [20, 24]. Soil texture found in the study area was sandy and sandy loam. Soil texture is a very important parameter which has a function to hold water and responsible for the aeration and also plays vital role in soil fertility [25].

Results showed the satisfactory concentration of organic matter (1.62%) which indicated the favorable condition for plant growth. Different studies have highlighted the role of organic matter in growth and abundance of plants [20, 26–28]. pH of soil sample was found alkaline (7.6–7.8). All nutrients in soil are easily available to plants at 7–7.5 pH, but at above pH range micronutrients are not available easily to the plants. The negative relationship

Fig. 4 T-value biplot of macronutrients and micronutrients

between pH and EC was studied by Regassa in the year 2005 [29].

According to Regassa, lesser nutrients will be available in soil to plants if the soil has higher pH and lower EC. Beneficial microbes are available at lesser soil pH. Likewise, nitrogen fixing bacteria are present at 6–8 soil pH. By using direct ordination techniques like CCA, relative position of species does not influence by making clusters and accurate response can be achieved by showing abundance [30, 31]. GAM as a direct gradient technique is proved as the best modeling technique to show the plant response toward environmental gradients. The present study revealed that

Cynodon Dactylon was most resistant species over the prevailing condition of soil pH, EC, potassium, phosphorus, zinc, iron, copper and manganese concentration ranges in Tharparker. Similarly, the study of Bashir et al. [14] showed the potential of *Cynodon Dactylon* on different recorded concentrations of edaphic factors.

Fig. 5 Growth response of species against concentration range of pH, EC and macronutrients

Fig. 6 Growth response of species against concentration range of micronutrients

3 Conclusions

The present study was conducted to classify and assess the herbaceous flora in Tharparker by employing TWIN-SPAN, DCA and CCA. Different responses of every species toward environmental variable were recorded and developed visually by scaling models. Model represented the greater abundance and regular distribution of *C. dactylon* at a wide range of analyzed soil parameters. The analyzed concentration of micronutrients and macronutrients was found effective in the growth of every species; in particular, pH, zinc and moisture have greater influence on species frequency and abundance. This study is a model study to set a step forward for detailed study about the herbaceous vegetation in Tharparker, because of its importance as a protected area. It is needed to accomplish and monitor the natural resources. This will also help in making decision to manage the present condition and adopt better conservation practices for herbaceous flora that account 60% of Tharparker vegetation.

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Compliance with ethical standards

Conflict of interest The authors have no conflict of interest. The authors did not cause any damages and harm to the protected area. It is open to all for research in Pakistan.

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