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Evaluation of ecological aspects of natural vegetation of Pakpattan District using multivariate techniques

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Abstract

A survey of natural vegetation, soil and water of Pakpattan District was undertaken in this study. Floristic data was analyzed by using multivariate analysis techniques i.e., Tow- way Indicator Species Analysis (TWINSPAN) and Canonical Correspondence Analysis (CCA). A total of fifty six species related to nineteen families were documented from forty quadrats in Pakpattan district. Two major and six sub plant communities were identified in the study area. The study also investigated the relationship of vegetation structure to selected environmental factors. This relationship was determined by CANOCO analysis. The distribution of species in relation to environmental variables indicated that although most of the variables were strongly correlated but failed to play major function in the grouping together of the species. This study also provided important information to preserve and improve the existing vegetation cover for conservation of indigenous flora.

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Introduction

Pakpattan which fall in arid hot sub- tropical monsoon- rains region of Punjab is located 190 km from Lahore and 45 km from Sahiwal. Agriculturally, it comprises land with a very high economic potential under irrigation. Moisture shortage is the major problem and being met by tube wells. It includes 152 km² of moderately deep silty soils with sand at 60-90 cm. which can be used for major crops of the area except rice and orchards. A part consists of slightly saline soils that can be ameliorated by leaching with good quality water. About 178 km² constitute clayey soils having high potential for irrigated agriculture. The geographical location of Pakpattan district is 30°22′231″N 73°16′851″E.

The aim of this research was to quantify the vegetation in Pakpattan district using ordination techniques and to quantify various adaphic and hydrological characteristics of the study area. For classification and ordination analysis of vegetation types, cluster analysis was performed by Two-way Indicator Species Analysis (TWINSPAN). Ordination techniques are frequently used in phytosociology. Two way Indicator Species Analysis (TWINSPAN) is a classification technique wherein, stands are classified and then this classification serve as the base for the classification of species (Hill, 1979). A study was conducted by Malik and Husain (2006) at Lohibehr Reserve Forest and its surrounding areas in Rawalpindi, Pakistan for the analysis of plant communities through TWINSPAN and identified four plant communities in the area. Ahmad (2009) conducted a study on the herbaceous vegetation of Margalla Hills National Park, Islamabad, Pakistan and recorded its growth, distribution and classification attributes. About 52 herbs belonging to 26 families were documented through 30 quadrats and four plant communities were recognized by TWINSPAN analysis. Ahmad and Rafique (2010) surveyed the vegetation along Nallah Korang in Islamabad, Pakistan, using two way indicator species analysis (TWINSPAN). Three major plant communities were identified, on the basis of the sharing of common characteristics in terms of habit and life form by the plants. A similar study was carried out by Ahmad and Yasmin (2011) of natural vegetation along Hana Lake, Baluchistan, Pakistan in order to classify the vegetation into plant communities, by analyzing vegetation data through TWINSPAN. The study area was divided into two zones. In both the zones two major and four sub communities were identified. Ahmad *et al.*, (2014) carried out a survey of Changa Manga Forest (CMF) and identified 45 species belonging to 24 families from the forest area. The TWINSPAN analysis of the vegetation data showed *Parthenium hysterophorus, Malvestrum cormendalianum, Oxalis corniculata, Cynadon dactylon, Desmostachya bipinnata* as dominant species in all the four zones of the area.

The composition of vegetation in a community is determined by many factors and ordination helps in identifying those factors (parameters) which are most important among them. Canonical Correspondence Analysis (CCA) developed by Ter Braak (1988) was selected for ordination. Its associated computer package is known as CANOCO (Ter Braak, 1988). The environmental variables and the vegetation data can be included within the ordination simultaneously while performing Canonical Correspondence Analysis. Thus input to CCA comprised of the species and quadrats data and also another data set consisting of environmental variables (Kent and Coker, 1995). The result is a consolidated ordination of species along with the associated environmental factors. CCA, hence, shows major links between species and the ecological (environmental) factors and moreover describes the relationship of the group to measured ecological factors (Kashian *et al.,* 2003). Various studies in different parts of the world described the application of CCA in the ordination methods as a useful tool.

Multivariate analysis of vegetation data of Hudiara Drain surroundings was carried out by Ahmad *et al.*, (2010) using CANOCO 4.5 software. Two major communities were identified. CCA exhibited that the

environmental factors influenced the distribution of vegetation but their role in the assemblage of species was not significant. A study was carried out on roadside vegetation and soil along Lahore-Islamabad motorway (M-2) by Ahmad (2011). Three hundred and ninety seven plots were sampled to document the percentage cover values of 227 species. The collected data was subjected to canonical correspondence analysis in order to find out the floristic structure and its correlation with the selected edaphic factors. Ahmad and Ehsan (2012) conducted a research in the Lohibehr Wild Life Park, near Islamabad to identify the grouping of plant species with regard to environmental variables. Canonical Correspondence Analysis (CCA) was used to analyze the floristic composition. This study also provided the necessary information for the preservation and improvement of native vegetation growing along the roads.

Materials and methods

The quadrat method of sampling was used for plant data collection. Sampling with quadrat of 1m² for grasses, 5 m² for shrubs and 10 m² for trees was carried out. In each quadrat percentage cover of all vascular plant species was estimated by visual observations as described by Kent and Coker (1992). The sampling was carried out twice a year i.e., during February and September. As vegetation was homogenous in structure and floristic composition, random sampling was performed.

Plant species were identified with the help of Flora of Pakistan (Nasir and Ali, 1970-1989; Ali and Nasir, 1990-1992; Nasir and Rafique, 1995; Ali and Qaisar, 1992-2010). Vegetation data was analyzed by multivariate techniques such as TWINSPAN and CCA. Soil and water samples were collected from the study area for analysis. A 0-15 cm topsoil layer was sampled from each quadrat using stainless steel hand auger because most of the nutrients absorbed by the plant are present in this zone (Allen 1989). Soil samples were prepared for laboratory analysis (EC, pH, texture, colour, water content) following standard procedures. Soil pH and EC was measured after taking 1:5 soil water extract. Similarly ground water samples were recorded for their pH, EC and water table depth.

Results and discussion

The results of the study are sectioned into two parts. First part describes the results of plant species analysis utilizing TWINSPAN and second part describes the results of CCA analysis of vegetation.

TWINSPAN Classification of Species at Pakpattan Study Area

A total of fifty six species related to nineteen families were documented from 40 quadrats in Pakpattan study area.In order to classify the vegetation types, cluster analysis was performed by TWINSPAN (Hill, 1979). Depending upon the analysis eight major vegetation types were identified. The results are presented in the form of a dendrogram in Fig. 1. These results clearly indicate that at the first level TWINSPAN divided the vegetation of the whole study area into two major communities at association level that are further divided into sub communities at sub association level. Each major and sub- community was named following the most important dominant species.

Abbreviations for the plant species represented in Fig.1 and 2 are presented in Table 1.

Table 1. Abbreviations for Plant Species Displayed in Fig.1 and 2.

Sr. No.	Species	Abbreviations
1.	*Acacia nilotica*	*Aca-nil*
2.	*Albizia lebbeck*	*Alb-leb*
3.	*Aloe vera*	*Alo-ver*
4.	*Alternanthera pungens*	*Alt-pun*
5.	*Alternanthera* sessilis	*Alt-ses*
6.	*Amaranthus viridis*	*Ama-vir*
7.	*Atriplex crassifolia*	*Atr-cra*
8.	*Azadirachta indica*	*Aza-ind*
9.	*Butea monosperma*	*But-mon*
10.	*Calotropis procera*	*Cal-pro*
11.	*Capparis decidua*	*Cap-dec*
12.	*Capparis spinosa*	*Cap-spi*
13.	*Cassia absus*	*Cas-abs*

Sr. No.	Species	Abbreviations
14.	*Chenopodium album*	*Che-alb*
15.	*Chenopodium murale*	*Che-mur*
16.	*Chrozophora tinctoria*	*Chr-tin*
17.	*Citrullus colocynthis*	*Cit-col*
18.	*Conyza bonariensis*	*Con-bon*
19.	*Cordia myxa*	*Cor-myx*
20.	*Crataeva adansonii*	*Cra-ada*
21.	*Cuscuta reflexa*	*Cus-ref*
22.	*Cynodon dactylon*	*Cyn-dac*
23.	*Dalbergia sissoo*	*Dal-sis*
24.	*Datura fastuosa*	*Dat-fas*
25.	*Desmostachya bipinnata*	*Des-bip*
26.	*Dichanthium annulatum*	*Dic-ann*
27.	*Digera muricata*	*Dig-mur*
28.	*Echinochloa colona*	*Ech-col*
29.	*Eucalyptus citriodora*	*Euc-cit*
30.	*Euphorbia prostrata*	*Eup-pro*
31.	*Fagonia indica*	*Fag-ind*
32.	*Ficus benghalensis*	*Fic-ben*
33.	*Ficus racemosa*	*Fic-rac*
34.	*Ficus religiosa*	*Fic-rel*
35.	*Imperata cylindrica*	*Imp-cyl*

Sr. No.	Species	Abbreviations
36.	*Melia azedarach*	*Mel-aze*
37.	*Morus alba*	*Mor-alb*
38.	*Parthenium hysterophorus*	*Par-hys*
39.	*Phoenix dactylifera*	*Pho-dac*
40.	*Phyla nodiflora*	*Phy-nod*
41.	*Prosopis cineraria*	*Pro-cin*
42.	*Ricinus communis*	*Ric-com*
43.	*Saccharum bengalense*	*Sac-ben*
44.	*Salvadora oleoides*	*Sal-ole*
45.	*Sesbania sesban*	*Ses-ses*
46.	*Setaria verticillata*	*Set-ver*
47.	*Solanum nigrum*	*Sol-nig*
48.	*Suaeda fruticosa*	*Sua-fru*
49.	*Tamarix aphylla*	*Tam-aph*
50.	*Trianthema portulacastrum*	*Tri-por*
51.	*Tribulus terrestris*	*Tri-ter*
52.	*Withania somnifera*	*Wit-som*
53.	*Xanthium strumarium*	*Xan-str*
54.	*Zaleya pentandra*	*Zal-pen*
55.	*Ziziphus mauritiana*	*Ziz-mau*
56.	*Ziziphus nummularia*	*Ziz-num*

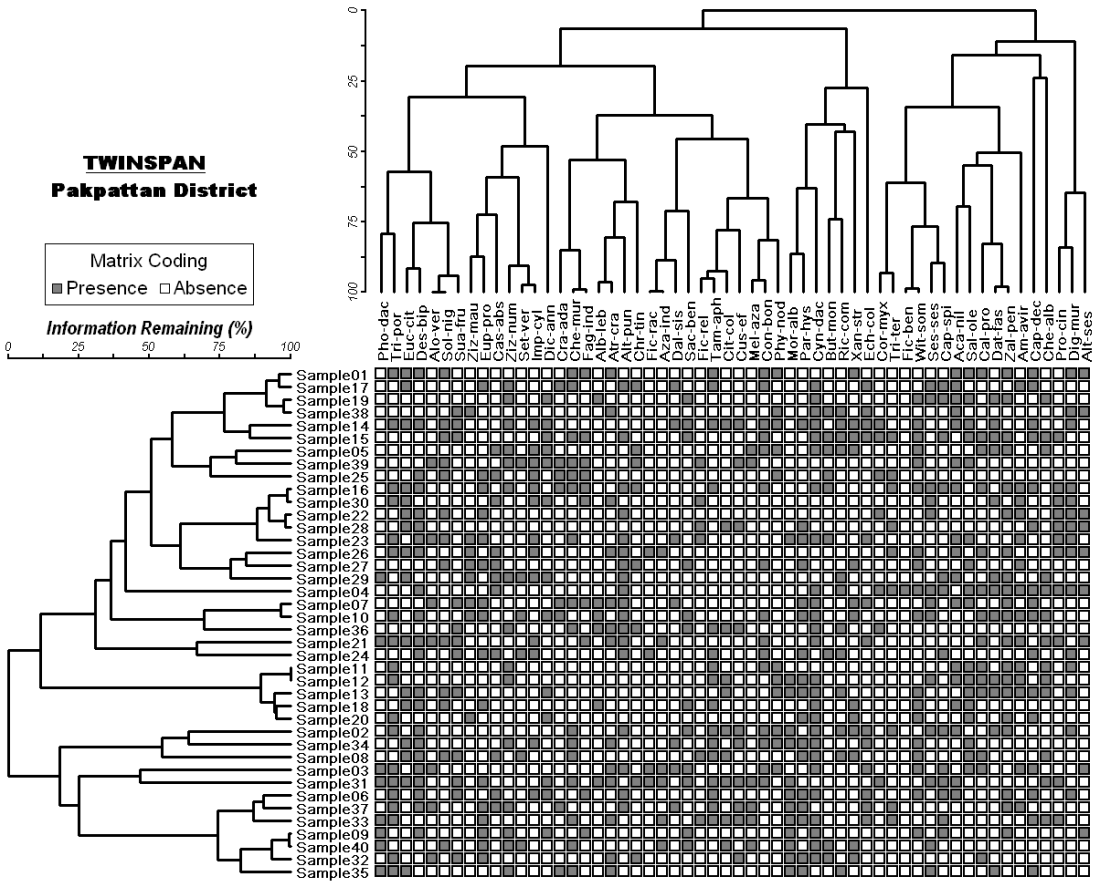

Fig. 1. TWINSPAN Analysis of Species at Pakpattan Study Area.

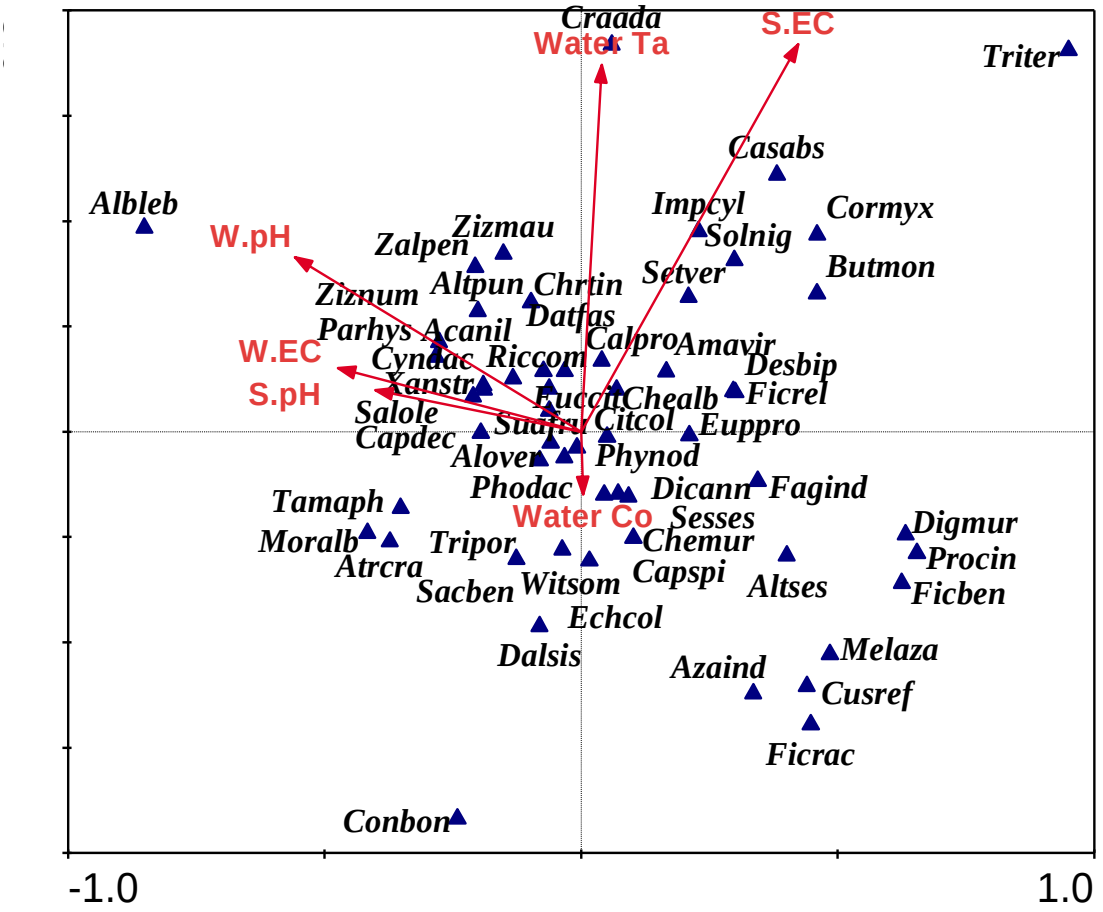

Fig. 2. Biplot Diagram of Species and Environmental Variables for Pakpattan.

Major Community 1: The major community 1 was designated *Cynodon dactylon* and *Desmostachya bipinnata* due to the highest occurrence of the said species in the area.

Major community 1 is further divided into following sub- communities:

1.1 *Desmostachya bipinnata* and *Trianthema portulacastrum*

1.2 *Alternanthera pungens* and *Tamarix aphylla*

1.3 *Cynodon dactylon* and *Parthenium hysterophorus*

Major Community 2: *Zaleya pentandra* and *Withania somnifera*

The major community 2 was designated as *Zaleya pentandra* and *Withania somnifera* due to the highest presence of *Zaleya pentandra* and *Withania somnifera* species in the area.

Major community 2 was further divided into following sub- communities:

2.1 *Zaleya pentandra* and *Withania somnifera*

2.2 *Capparis decidua* and *Chenopodium album*

2.3 *Digera muricata* and *Prosopis cineraria*

1.1 *Desmostachya bipinnata* and *Trianthema portulacastrum*

Desmostachya bipinnata and Trianthema portulacastrum group developed on the waste lands and along roads on the banks of River Sutlaj near Pakpattan city. Although this group occurred in only eight quadrats, but the exclusive species exhibited a fairly good cover values e.g. *Desmostachya bipinnata* 20% and *Trianthema portulacastrum* 15%. *Desmostachya bipinnata* is a grass of exposed and

dry places, covering open ground. The presence of this plant is an indicator of moisture present in the deeper layers of soils. Its roots penetrate in the deeper layers of soils to absorb moisture. In this plant the roots are approximately three to eight times longer than the aerial parts (Chaghtai *et al*., 1989). *Trianthema portulacastrum* is herb commonly called desert horse purslane. It can grow in all types of habitats but can easily establish in disturbed areas and agricultural fields in the form of a weed. It is an annual herb that can spread prostratly on the ground thus forming a clump or mat in which stems extends up to one meter. It is propagated by seeds and by fragments of stem which propagate from cuttings very easily. It occurs in waste lands and roadsides, if the water supply is low (Holm *et al*., 1997). Mostly it is found in regions of low seasonal rainfall (Henty and Pritchard, 1975). This group mostly comprised of herbaceous flora including *Aloe vera*, *Solanum nigrum, Suaeda fruticosa*, *Euphorbia prostrata* etc. The total number of species in this sub community was fourteen.

1.2 *Alternanthera pungens* and *Tamarix aphylla*

Alternanthera pungens and *Tamarix aphylla* sub community was the largest sub community separated by TWINSPAN Clustering for Pakpattan data. This community showed its existence in the vicinity of old River Bias both on edges of roads running along the river and waste lands near the river. This sub community comprised of almost 18 species. *Alternanthera pungens* colonies bare disturbed or over grazed areas usually forming a dense mat and out-compete more desirable species. Its large tap root makes its control difficult as if arial parts are removed the plant again propagates with help of its roots (Smith, 2002). *Tamarix aphylla* is an evergreen tree and is found along roads in arid areas. It is regarded as the most dominant species of this region. Successful vegetative propagation of *Tamarix* is responsible for its wide dispersal as the seeds of the plant are sterile (www.FAO.orgh/WAICENET/FAOINFO/AGRICUL.doc). Besides the two dominating species the other major species present in the community were *Chenopodium murale, Conyza bonariensis, Atriplex canescens, Saccharum bengalense, Phyla nodiflora, Fagonia indica*. All were herbaceous species, thus supporting the fact that herbaceous flora was well established. This group occurred in ten quadrats and exclusive species exhibited a fairly good frequency values e.g., *Alternanthera pungens* 45 % and *Tamarix aphylla* 40 %.

1.3 Cynodon dactylon and Parthenium hysterophorus

This sub community having *Cynodon dactylon* and *Parthenium hysterophorus* was found growing along edges of most roads in the entire urban and rural gradient of Pakpattan district. The dominants of this community were *Morus alba*, *Ricinus communis, Xanthium strumarium* and *Echinochloa colona*. *Cynodon dactylon* is commonly called devils grass as it leaves no place to make its existence and manages to exist in poor soils and is also drought resistant. Therefore shortage of water and hot climate increased its growth. While *Parthenium hysterophorus* is a fast growing species widely occurring in the sub-continent along roadsides and waste lands (Javaid and Anjum, 2005). Both the species were widespread in disturbed habitats such as along roads, overgrazed, trampled areas, waste lands etc. (Martin *et al*, 1951). The dominant species of this community occurred in 70% quadrats and the percentage cover values were also high for these species.

2.1 *Zaleya pentandra* and *Withania somnifera*

This group comprised of same dominant communities as that of major community 2. The sub community *Zaleya pentandra* and *Withania somnifera* showed their presence growing as weed in waste places and along edges of agricultural crop fields in the rural areas outside the Pakpattan city. The area was undisturbed and the community flourished there successfully. *Zaleya pentandra* is regarded as a common weed of cultivated areas. It is a prostrate perennial herb. *Withania somnifera* is a perennial shrub from the Solanaceae family, found along with

Z. pentandra on margins of cultivated fields. During the growing period plant do not require much moister. It can withstand temperature between 20 to 38°C. The microclimate required by two dominant species appeared to be quite similar to each other. *Zaleya pentandra* and *Withania somnifera* propagate quickly by seeds and both require hot climate for their growth. That is why this community existed in areas favoring their microclimate conditions. Pakpattan district occurs in the arid hot sub- tropical monsoon- rain region that is normally much hot and low rain fall area so these species flourished there successfully.

2.2 *Capparis decidua* and *Chenopodium album*

This was a very small group comprising of only two species which were making their separate group and occurred mostly in the quadrats layed down with in Dal Varyam plantation and its adjacent areas. *Capparis decidua* is a densely branching shrub of dry areas. The plant is under grave browsing pressure from animals like goat, sheep etc. and subjected to uncontrolled cutting from locals for a long period. There is a concern that heavy grazing may lead to a decline in population size and as a result the genetic consequences of small isolated population may result. *Chenopodium album* is a rapidly growing annual weedy plant belonging to genus *Chenopodium*, now occurs almost everywhere, especially on wasteland. It particularly likes disturbed soil. It is also seen growing as weed of fields. Both the species prefer sandy clay loam to sandy loam. The reason of *Chenopodium album* occurrence in association with *Capparis decidua* seemed to be its dispersal by seeds which are light weight and dispersed easily by wind to far off places. This group was recorded from five quadrats and the exclusive species exhibited good frequency values i.e., Capparis *decidua* 40 % and *Chenopodium album* 32.5 %.

2.3 *Digera muricata* and *Prosopis cineraria*

The sub community comprised of *Digera muricata* and *Prosopis cineraria*. These species existed together due to same microhabitat requirements and ecological characteristics. Members of this sub community marked their appearance in waste and disturbed habitats near Pakpattan Canal. *Digera muricata* is herbaceous annual plant that can grow from 20 to 70 cm tall. It is found growing most commonly on agricultural lands disturbed and waste grounds. It occurs in many kinds of habitat, from dry and semi-desert to moist localities. *Prosopis cineraria* is a flowering tree belonging to Fabaceae family, that is widespread in ar`id areas. The percentage cover values of these species were fairly high i.e., *Prosopis cineraria* 14.7 % and *Digera muricata 10* %. The group was recorded from six quadrats and comprised of only three species: hence it was not divided further. The lowest occurring species *Alternanthera sessilis*, was found in only 9 quadrats.

CCA Analysis of Vegetation and Environmental Variables for Pakpattan

In order to understand vegetation, soil and water correlation another multivariate technique Canonical Correspondence Analysis (CCA) was applied. In canonical correspondence analysis (CCA) the floristic data and environmental parameters were included with in the ordination simultaneously. Thus the input to CCA besides species and quadrats data included another data set of environmental variables (Kent and Coker, 1992). The result was an integrated ordination of species along with associated environmental variables. CCA, hence, explicates the affiliations of the groups to compute environmental variables and also shows the main links between the species and environmental variables (Kashian *et al.*, 2003). In addition to species data environmental data were included on pH, EC and soil water content as soil variables and pH, EC and water table depth as water variables in the software. Overall, by analysis of the biplot figure (Fig. 2), the impact of water pH and EC, Soil pH and water content seemed to influence the distribution of species reasonably well along two axes. The distribution of species in relation to environmental variables indicated that although most of the variables were strongly correlated but failed to

play major function in the grouping together of the species. The arrows for the water pH, EC and soil pH were pointing in the same direction showing a positive correlation with each other, on the other hand arrows for water table and soil EC were in opposite direction depicting no strong correlation with other environmental factors. Most of the species were grouped in the center of biplot diagram. Water pH seemed to portray some role in grouping together of *Albizia lebbeck, Ziziphus nummularia* and *Acacia nilotica*. Whereas, *Parthenium hysterophorus, Cynodon dactylon, Xanthium strumarium* and *Salvadora oleoides* were more strongly influenced by water EC and Soil pH along axis 1. Water content was less correlated with species, as there were less species covering the water table arrow. Longest arrow was of soil EC and species near this arrow, having strong correlation with this environmental factor were *Cassia absus, Imperata cylindrica* and *Solanum nigrum*.

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