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CLASSIFICATION AND ORDINATION OF VEGETATION COMMUNITIES OF THE LOHIBEHR RESERVE FOREST AND ITS SURROUNDING AREAS, RAWALPINDI, PAKISTAN

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Abstract

Agglomerative clustering, Two Way Indicator Species Analysis (WINSPAN), and Detrended Correspondence Analysis (DCA) were used for the plant community analysis. Remotely sensed data was used as a surrogate in identifying and locating field sites from where floristic composition, environmental and spatial data were collected. Characteristic plant species of each community type are presented together with the information on dominance and sub-dominance species. Four plant communities were recognized. Classification and ordination techniques provided very similar results based on the floristic composition. The results formed the basis for the mapping spatial distribution of vegetation communities using image analysis techniques.

Introduction

The Lohibehr scrub forest on the west of Rawalpindi district was declared as a Lohibher National Wildlife Park in 1987, spreading over an area of 440 hectares. This park is recent in origin, before that it was recognized as part of a scrub forest series raised artificially (Lohibher history files, 1989-90) in Pakistan, and due to its location in the immediate vicinity of heavily populated city Rawalpindi, increasing commercial and urban developments and high grazing pressure prone to biotic interferences. Southeastern and northern sides have under gone steady urban development for approximately last ten years and thus containing diversity of residential and commercial areas resulting in remaining forest cover under intensive development pressure (Malik *et al*., 1999).

Almost half of the forested area has been converted into non-forested area, and would be unproductive if proper management is not undertaken. Unfortunately the latest vegetation map of the Park is also not available; therefore the study site was selected as an appropriate location for a variety of remote sensing studies focusing on land use/cover data to prepare and update detailed vegetation map and its periodic monitoring with out disturbing the ecosystem. Synoptic and repetitive coverage of satellite data in the past has proved very helpful for the monitoring of vegetation and management of national parks (Verhoeye & De Wolf, 2002).

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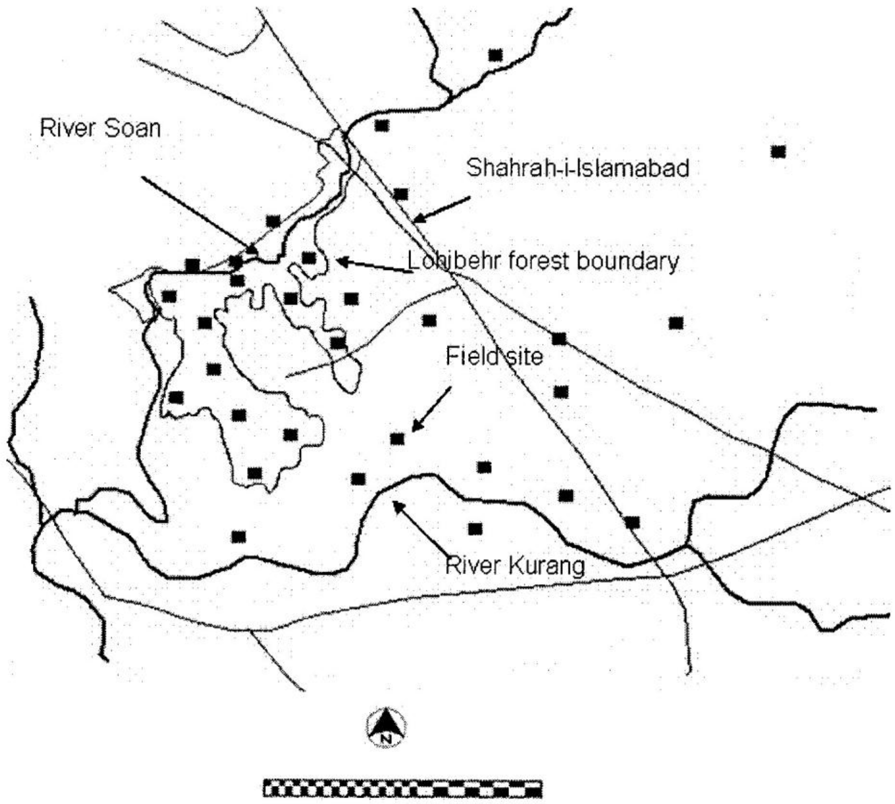

Fig. 1. Location of the field sites where floristic data were collected. Numbers inside the Lohibehr forest indicate different compartments.

Study area: The Lohibehr study site, is located between 33^0 34' and 33^0 36' north and 73^0 05' and 73^0 06' east at an altitude of 500 metres, situated at a distance of 16 kilometres from Islamabad on the right side of the Islamabad-Lahore Highway. The site is bounded to the north by Chaklala airport, to the west by Lohibehr village and the Soan river runs along the eastern and southern sides (Fig. 1). The physical features of the site exhibit a variety of plateaus, hillocks, valleys, ravines, streams, plains and other forms of topography. The rock formation is composed of tertiary sandstone and alluvial deposits. The western and northern portion is a plain with clayey loam soil and the hillocks are made of alluvial material with a large number of stones cemented together (Leh conglomerate). The sandstone apparently belongs to the Sirmur and Siwalik series of the sub-Himalayan system. The pebble ridges described as alluvial deposits are a peculiar feature of the Rawalpindi district and most of the forests in the district are on the pebble ridges. Large isolated boulders in many places seem to point to a glacial epoch in the Potohar plains. The Pothowar plains were formed during the Quaternary Period and they are composed of alluvium and gravel caps. Soils belong to the Rawalpindi Series which have been derived from loessic material

The climate of the area is sub-tropical continental lowland, sub-humid Pothowar plateau with a mean annual precipitation of 970 mm, most of which falls in the monsoon during the months of July and August. January is the coldest month (mean minimum temperature 0.6^0C) while June is the hottest (mean maximum temperature 45^0C). The highest relative humidities of 83% and 76% are recorded. The wind generally blows from northwest but during the monsoon season, its general direction is southeast.

The main drainage systems are the Korang and Soan rivers (Fig. 1). A large number of seasonal nullahas flow though the site beside the Korang river, part of which passes through the area. The area encloses large piece of private land on three sides and eight villages are located around the area. Most animals as well as some migratory herds tend to graze in the area, which caters for their grazing requirements.

Field data collection: Floristic data were collected from 90 randomly selected plots from 30 field sites selected subjectively**.** Each field site comprised an area of 1.44 ha, which is equal to 120mx120m or 6x6 pixels of satellite sensor data (SPOT XS). Three to five randomly located points from each site were sampled based on vegetation homogeneity/heterogeneity. For each plot floristic and geographic data were collected. The latitude and longitudes were recorded for each plot using a Global Positioning System (GPS). Field information about different vegetation types and other parameters such as deforestation, urban encroachment, grazing pressure, land-use/cover patterns, general topography of the area and cultivation were also recorded. Floristic data from each plot was recorded as a percentage cover which was assessed as the vertical projection onto the ground of all the above ground parts of the individuals expressed as a percentage of the reference area. The percentage cover recorded was then partitioned to the "DOMIN" scale (Kent & Coker, 1992). For recording the floristic data such as trees, shrubs, and ground flora, the methodology used by Rodwell *et al*., (1991) was adopted. Nomenclature follows Flora of Pakistan by Nasir & Ali (1972). For the species identification, the Flora of West Pakistan by Stewart (1972), the Flora of Pakistan by Nasir & Ali (1970) and Nasir (1980) and checklist of plants of Margalla Hills by Yasin & Akhter (1987) were used.

Data analysis: All the species data, as well as the field plots, were used for the analysis. All classification methods were used on the raw data as recommended by Palmer (2002). No transformation of floristic data was used. The *PC ORD ver. 3.05* (McCune & Mefford, 1997) was used for TWINSPAN classification and ordination analysis. *R Package 4.06* (Legendre & Vauder, 1991) was used for agglomerative clustering. For classification, floristic data were analyzed by TWINSPAN and agglomerative cluster analysis techniques. For agglomerative clustering data were analyzed using different similarity indices and some of these use qualitative data, based on presence/absence, while others are quantitative and work on abundance data. Three similarity indices such as Jaccard's index (S_7), Sørensen's index (S_8), Steinhous index (S_{17}) were used for agglomerative clustering (Legendre & Legendre, 1998). There are several methods of clustering algorithms (sorting strategies) available and in this study three different methods such as "UPGMA" ('Unweighted Pair-Groups Method using Arithmetic averages') Proportional-Link Linkage' by Sneath & Sokal (1973), and Ward's method of minimum variance (Kent & Coker, 1992) were used. Cophenetic correlations such as "Kendall's tau b cophenetic correlation" and "Pearson's r cophenetic correlation" were calculated for comparing the results of the agglomerative clustering methods.

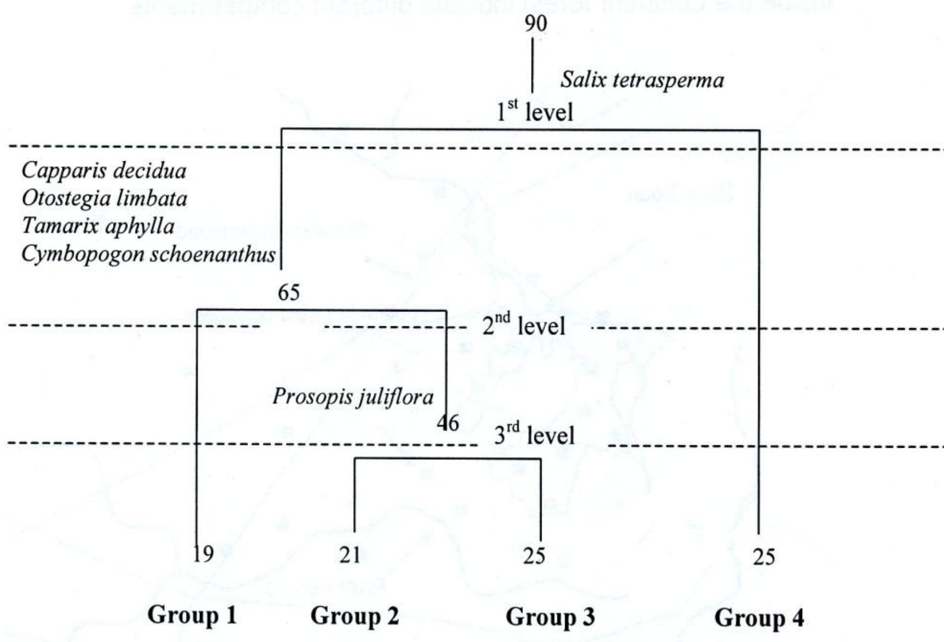

Fig. 2. TWINSPAN classification.

The second method used for the classification of floristic data was TWINSPAN (Hill, 1979), a commonly used program in ecological studies. Greig-Smith (1983) suggested that the presence of the species rather than its abundance should be dominant in numerical vegetation classification. Therefore, the analysis employs the presence/absence data and not the cover value of each species. Classification by TWINSPAN was stopped at the 3rd level so that the size of stands would demonstrate ecological meaning through their floristic structure. This resulted in four distinct groups, which are presented in dendrogram (Fig. 2), together with the indicator species used by the software for every level of division. Although the dendrogram is not as detailed as the TWINSPAN table, it summarizes the results in a more convenient way.

Third method used was ordination analysis that employed abundance data using the 'Domin scale' without any transformation. Preliminary analysis using Principal Component Analysis (PCA) and Detrended Corenrpondance Aanalysis (DCA) suggested that ordination using DCA provided more robust and interpretable results than PCA and the length of first axis was greater than 3.0 and in terms of species turnover or standard deviation (s.d). It is recommended by Jongman *et al*., (1995) and Palmer (2002) that if species turnover is greater than 1.9 s.d then DCA is better choice of ordination. Therefore PCA was discarded from further analysis. Detrended Correspondence Analysis (DCA) were performed to describe compositional gradients in the vegetation. DCA was performed using a default value for detrending and rescaling. For detrending a default value "26" recommended by the ter Braak (1987) was used. Rare species were downweighted in DCA ordination.

Table 1. Degree of fidelity (modified from Kent & Coker, 1992).

Fidelity 5	Character species	Exclusive taxa	Completely or almost completely confined to one community
Fidelity 4	Character species	Selective taxa	Species occurring with clear preference for one community but also occurring rarely in other communities
Fidelity 3	Character species	Preferential taxa	Present in several communities more or less abundantly but predominantly in a certain community and there with a great deal of vigour
Fidelity 2	Companions	Indifferent taxa	Without any pronounced preference for any particular community
Fidelity 1	Accidentals	Strange taxa	Species which are rare and accidental intruders from other community or relics of a preceding community

Results

Based on the floristic composition, all the plots were classified into 4 plant community types. The characterization of the identified vegetation groups into named community types was based on the concepts of fidelity and constancy. Fidelity refers to the degree to which species are confined to particular groups of plots. Fidelity is dependent on the size of the area surveyed (ideally it should be assessed only when the vegetation of an area has been described). Therefore constancy (refers to the number of times each species is present in the plots that belong to a specific vegetation group) was also used to name the groups identified. Species with a constancy between 20% and 75% that occurred together in more than one plot, while at the same time having a degree of fidelity between 3 and 5 (on a scale from 1 to 5 after Kent & Coker, 1992), were termed '*characteristic species*' and were used to name each community (Table 1). Characteristic plant species of each community type are presented in Table 2 together with the information on the dominant and subdominant species. The vegetation units identified here are referred to as 'community types' (Muller-Dombois & Ellenberg, 1974).

The dendrogram (Fig. 2) was produced using different similarity indices and the sorting strategies were evaluated for their differences, and their usefulness for plant community analysis and satellite data interpretation. The results were compared with the classification produced from the TWINSPAN clustering method.

The description of the community types is based on classification analyses using different methods. Lines drawn on the dendrogram for defining community types have been drawn arbitrarily as discussed in Legendre & Legendre, (1998). Very similar groups were obtained from Sørensen's and Jaccard's similarity coefficients (S_7 and S_8). Even when different sorting criteria were used, this does not affect the grouping results.

Most of groups produced from S_7 and S_8 were more similar to each other than the groups obtained using S_{17}, which was calculated using abundance data. The reason for the consistency between the different methods is that data show a relatively clear group structure. For separation of the community types, Unweighted Arithmetic Average (UPGMA) and Proportional Link Linkage (connectedness 0.50) clustering methods were probably the best and also produced higher cophenetic correlations (Table 3).

Table 2. Community types with their characteristic species.

Community type	Characteristic species	Dominant Species	Degree of fidelity (1–5)	Constancy (%)
Ziziphus-Malcolmia	*Ziziphus nummularia*	*Acacia modesta*	3	68.00
	Malcolmia africana	*Lantana camara*	4	36.00
	Acacia nilotica	*Justicia adhatoda*	3	72.00
Prosopis-Chrysopogon	*Prosopis juliflora*	*Heteropogon contortus*	4	74.50
	Chrysopogon montanus	*Desmostachaya bipinnata*	3	28.57
	Xanthium strumarium		3	61.90
	Withania somnifera		3	52.38
	Cenchrus ciliaris		3	61.90
Capparis-Eleusine	*Capparis decidua*	*Capparis decidua*	5	74.74
	Tamarix aphylla	*Chrysopogon montanus*	5	70.95
	Eleusine compressa	*Desmostachaya bipinnata*	4	74.74
	Cymbopogon schoenanthus	*Dicanthium annulatum*	3	64.21
	Otostegia limbata		3	73.68
Salix-Saccharum	*Salix tetrasperma*	*Desmostachaya bipinnata*	5	60.00
	Saccharum benghalensis	*Saccharum spontaneum*	4	28.00
	Ricinus communis	*Typha augustifolia*	4	36.00
	Juncus articulatus	*Cynodon dactylon*	5	36.00
	Nasturtium officinale		5	28.00
	Cynodon dactylon		3	68.00
	Vicia sativa		4	36.00
	Plantago lanceolata		3	36.00

Table 3. Cophenetic correlations of different agglomerative clustering.

	Similarity matrices	Sorting strategies		
		UPMGA	**Proportional link linkage**	**Ward's method**
Pearson's r	S_7			
	S_8	0.84	0.84	0.80
	S_{17}	0.87	0.87	0.81
Kendall's tau b	S_7	0.66	0.66	0.64
	S_8	0.67	0.66	0.66
	S_{17}	0.68	0.68	0.66

The TWINSPAN analysis divided the field plots into four vegetation clusters, each cluster representing a specific community type with characteristic species (Fig. 2). Three clusters had a single characteristic species, while the other was characterized by the presence of four species which were restricted mostly to it. TWINSPAN classification initially separated all the plots into two broad groups: groups of 65 and 25 plots with *Salix tetrasperma* as a key indicator species. The second level of division separated the group of 65 plots into two groups of 19 and 46 plots. This division was based on the presence of *Capparis decidua, Otostegia limbata, Tamarix aphylla,* and *Cymbopogon schoenanthus* as the negative group. The third level of division separated the group of 46 on the left side of the dendrogram into two new groups of 21 and 25 plots where *Prosopis juliflora* was the positive indicator species.

Four plant community types were recognized from the TWINSPAN and agglomerative clustering which were later used with the multispectral classification of SPOT XS data (Malik & Husain, 2006).

Capparis decidua-Eleusine compressa (Group 1 in Fig. 2 and referred to as *Capparis-Eleusine* community type) community type is heavily grazed and subject to uncontrolled cutting for a long period. Due to biotic pressures, all trees have been completely eliminated. This community type is represented by few open scattered shrubs, which include *Capparis decidua, Otostegia limbata, Tamarix aphylla, Periploca aphylla,* and *Ziziphus nummularia. Capparis decidua* seems to withstand the biotic pressure better than other species, so it dominates the shrubs. Grasses forms a more or less continuous association over appreciable areas. *Eleusine compressa, Chrysopogon montanus, Cymbopogon schoenanthus, Heteropogon contortus* and *Desmostachya bipinnata* were among the grass species. This community type was found mostly on gravelly, eroded hill slopes and tops and in the crevices of exposed rocks. *Lantana camara* and *Broussonetia papyrifera* were observed as invasive species in this community type.

Prosopis juliflora-Chrysopogon montanus *(*Group 2 in Fig. 2 & referred to as the *Prosopis-Chrysopogon* community type) is characterised by the presence of *Prosopis juliflora,* which covered a large area of Compartments 1 and 2 of the previously declared reserve forest. This community type is formed as a result of complete cutting of native forest vegetation for the construction of new housing schemes by the local development authority and is mostly confined to western aspects.

Prosopis juliflora is an invasive exotic but is naturalised in open and arid regions of Pakistan (Khatoon *et al.,* 1999; Hameed *et al.,* 2002) and constitutes a prominent feature of the vegetation of the plains. *Prosopis juliflora* does not depend entirely on the availability of surface moisture, but can extend its roots at least 20m into the soil to reach and tap the underground lenses of fresh water. Thus it resists the drought conditions and can survive provided the depth of soil is adequate in dry and arid tracts where vegetation of any other kind is scanty (Chaghtai *et al.,* 1989). *Desmostachya bipinnata* a grass of exposed and dry places, covering open ground is an indictor of moisture present in the deeper layer of the soils. In spite of higher rainfall compared to other drier areas nearby such as Attock and Chakwal, xeric conditions prevail due to the poor retention of moisture by the upper porous layers of the soil. *Desmostachya bipinnata* overcomes this by sending down its roots into the deeper layers of the soil. In this plant, the roots are 3 to 8 times the size of the aerial parts (Chaghtai *et al*., 1989). *Prosopis juliflora, Lantana camara,* and *Xanthium strumarium* were three invasive species found in this community type.

Ziziphus nummularia-Malcolmia africana (Group 3 in Fig. 2 & referred to as the *Ziziphus-Malcolmia* community type) covers a large area of the reserve forest. *Acacia modesta* forms the main canopy. Due to heavy biotic pressure, such as grazing, unpalatable species such as *Justicia adhatoda, Withania somnifera* and *Lantana camara* are conspicuous with thorny *Gymnosporia royliana, Woodfordia fruticosa, Ziziphus nummularia* and *Carissa opaca.* The under-canopy of this community is not thick with open patches cover with grasses. Regeneration of *Acacia modesta* is not high. Among the tree species, scattered trees of *Dalbergia sisso,* and *Acacia nilotica* were observed. At some places, *Broussonetia papyrifera* in Compartments 3 and 4 and *Prosopis juliflora* in Compartments 7 and 8 have invaded the community type. *Olea ferruginea,* always found in close association with *Acacia modesta* and *Carissa opaca* (Champion *et al.,* 1965) had either been completely eliminated or was present as scattered, stunt, bushy trees; less than two metres in height. *Dodonea viscosa,* another important member of scrub forest, is completely destroyed. This community type was found mostly along west facing slopes on dissected rolling plains. *Chrysopogon montanus, Heteropogon contortus,* and *Desmostachya bipinnata* are among the main grasses recorded in this community. *Broussonetia papyrifera, Lantana camara* and *Prosopis juliflora* were three invasive species recorded in this community type.

Saccharum benghalensis-Salix tetrasperma (Group 4 in Fig. 2 & referred to as the *Saccharum-Salix* community type) was found growing along streams and river beds, adjoining slopes, edges, and flood plains that are annually/seasonally flooded. The vegetation is highly influenced by the flooding. *Saccharum spontaneum*, a plant along the streams, rivers and their banks, dominated this community. Signs of grazing were evident and large clumps of *Saccharum spontaneum*, cut at ground level also hinted at human interference. In some places away from the river/stream banks, *Cynodon dactylon* was the major component. It covers open places among *Saccharum spontaneum*. In other places that were more dry and sandy, *Desmostachya bipinnata* was found in abundance. Plots sampled closer to the main stream, nallaha and river banks were physiographically gravel bars comprised of gravel, pebbles of varying sizes and with a small proportion of sand. Mostly these plots were the first to be submerged in flood periods and there had been lot of soil moisture in the soil and these plots were dominated by *Saccharum spontaneum*, which was found in small clumps accumulating, sand around it. These plots seemed to be in an advanced stage of succession as two woody species, viz., *Salix tetrasperma* and *Dalbergia sisso*, were reported. This habitat is suitable for the establishment of some other woody perennials too, such as *Ricinus communis, Acacia modesta* and *Acacia nilotica* etc., which were found growing around and might serve as seed sources. However it would be very difficult for these species to establish themselves due to the high competition from *Saccharum spontaneum*. These plots also support large number of annuals. Species like *Saccharum benghalensis* and *Ricinus communis* were also found among this community type. Close to the river and stream water, where high moisture was available, water loving species such as *Ranunculus arvensis, Rorippa nasturtium-aquaticum, Bacopa monnieri, Juncus* sp., *Anagallis* sp., and *Psammogeton* sp., *Fumaria indica, Convolvulus arvensis, Cyperus* sp., *Vicia sativa*, and *Verbena* sp., were found.

To compare the classification and ordination results, the vegetation groups obtained from TWINSPAN classification method were superimposed onto the CA/RA, DCA and CCA ordination diagrams. Abbreviations for plant species in the ordination diagram are presented in Appendix I. The results obtained for plots as well as for species ordinations using different techniques are described below. Detrended Correspondence Ordination technique was employed to find the underlying environmental gradients. The distribution of the sample plots along the DCA ordination axes is given in Fig. 3 overlaid with groups identified using TWINSPAN. The eigenvalues of the first three DCA axes were 0.36, 0.17 and 0.10 respectively (Table 4). The scatter diagram illustrates a moisture gradient along the horizontal axis, with the wetter habitats to the rights and drier habitats to the left. On the X and Y axes, a clear discontinuity exists between the flooded plains *Saccharum-Salix* community type from the scrub forest *Ziziphus-Malcolmia* community type. The flooded plain vegetation forms a strong group restricted to a specific area of the scatter diagram far from the rest of the vegetation community types which are distinct from each other along the Y axis. *Acacia modesta, Prosopis juliflora,* and *Capparis decidua* dominated vegetation types base themselves on the left of the diagram, while *Salix-Saccharum* vegetation type is on the right. The *Ziziphus-Malcolmia* community type was more widely dispersed and recorded on western slopes showing some overlap in the ordination space with vegetation types of degraded sites such as *Capparis-Eleusine* and *Prosopis-Chrysopogon* vegetation types. The *Capparis-Eleusine* community type was found on eroded hill tops and rock crevices mostly in Compartments 3, 4 and 5 of the reserve forest. On the bottom left of the ordination diagram, plots belonging to the *Prosopis-Chrysopogon* community type were recorded in Compartments 1 and 2 where forest vegetation has been destroyed for the construction of new housing.

Names of the species displayed in Fig. 4.

Species	Abbreviation
Acacia modesta,Wall,	Acamod
Acacia nilotica (Linn.) Del.	Acanil
Allium spp.	Allspp.
Anagallis arvensis L.	Angarv/Anaarv
Artemisia scoparia Waldst. & Kit.	Artrox/artsco
Bacopa monnieri (L.) Wettstein	Bacop/Bacmon
Barleria cristata L.	Barler/Barcri
Boerhavia repens L., var. procumbens Roxb.	Boerhsp.
Bromus sp.	Brosp.
Broussonetia papyrifera (L.) Venten.	Brospap
Cannabis sativa L.	Canbis/Cansat
Capparis decidua (Forssk.) Edgew	Capdec
Celtis eriocarpa L.	Celeri
Cenchrus ciliaris L.	Cencil
Centaurium centauriodes	Cencen
Chenopodium album L.	Chealb
Chenopodium murale L.	Chemu
Chrysopogon montana Vahl.	Chrymon
Conyza aegyptiaca Ait.	Conyaeg
Conyza bonariensis (L.) Cronquest.	Conybon
Conyza canadensis (L.) Cronq.	Concan
Coronopus didymus (L.) Sm.	Cordid
Cousinea sp.	Cousp.
Cymbopogon schoenanthus	Cymmon
Cynodon dactylon (L.) Pers.	Cyndac
Cyperus articulatus L.	Cypart
Cyperus niveus Retz.	Cypniv
Dalbergia sisso Roxb.	Dalberg
Datura stramonium L.	Datstra
Desmostachaya bipinnata L.	Desbip
Dichanthium annulatum (Forssk.) Stapf.	Dicanu
Diclyptera bupleuroides Nees.	Dicprox
Eleusine compressa L.	Elecom
Eucalyptus spp.	Eucspp
Euphorbia hirta L.	Euphir
Ficus foveolata L.	Ficfov
Fumaria indica (Hausskn.) H. N.	Fumind
Gagea pseudoreticulata	Gagpse
Galium trifolium L	Galtri
Geranium rotundifolium L.	Gerrot
Heteropogon contortus (L.) Beauv. ex Roem. & Schult.	Hetcon
Indigofera linifolia (Linn.) Retz.;	Indlin
Juncus articulatus L.	Junart
Justicia adhatoda L.	adatod/Jusadh
Lactuca sativa L.	Lacsat

(Cont'd.)

Species	Abbreviation
Lantana alba Roxb.	Projul
Lantana camara L.	Lcam/Lancam
Lathyrus aphaca L.	Lataph
Launaea procumbens L.	Laupro
Malcolmia africana (L.) R. Br.	Malafr
Mazus japonicus (Thunb.) Ktze.	Mazjap
Maytenus royleanus wall. ex Lawson	Maytnus/Mayroy
Medicago sativa L.	Medsat
Melilotus philippensis L.	Melphi
Nasturtium officinale R. Br.	Nasoff
Nerium indicum Miller	Nerind
Oenothera rosea L.	Oenros
Olea ferruginea Royle	Olea/olefer
Otostegia limbata (Bth.) Boiss.	Otolimb
Phleum sp.	Phlsp.
Plantago lanceolata L.	Plalen
Poa annua L.	Poaann
Polygonum plebgum R. Br.	Polyple
Potamogeton pusillus L.	Potpus
Ranunculus arvensis L.	Ranarv
Ranunculus muricatus L.	Ranmur
Ranunculus sceleratus L.	Ransce
Ricinus communis L.	Riccom
Rumex dentatus L.	Rumden
Saccharum bengalensis L	Sacben
Saccharum spontaneum L.	Sacspo
Sageretia thea var. brandrethiana Aitch.	Segthea
Salix tetrasperma Roxb.	Salixtet
Salvia plebejus L.	Salple
*Sida cordata (*Burm.f.) Bross.-Waalkes	Sida/sidcor
Sisymbrium irio L.	Sisiri
Solanum incanum L.	Solninc
Solanum stramonium L.	Solstr
Sonchus asper (L.) Hill	Sonasp
Tagetes minuta L.	Taget/tagmin
Tamarix aphylla (L.) H. Karsten	Tamaph
Taraxacum officinale GH Weber ex Wiggers.	Taroff
Trichodesma indicum L.	Triind
Tulipa stellata Hook. f.	Tulste
Typha angustifolia VK	Typaug
Veronica arvensis L.	Verarv
Vicia sativa L.	Vicia/vicsat
Withania somnifera (L.) Dunal.	Witsom
Woodfordia fruticosa (L.) S. Kurz.	Wood/woofru
Xanthium strumarium L.	Xanstru
Ziziphus nummularia (Burn. f.) Wight & Arn.	Ziznim

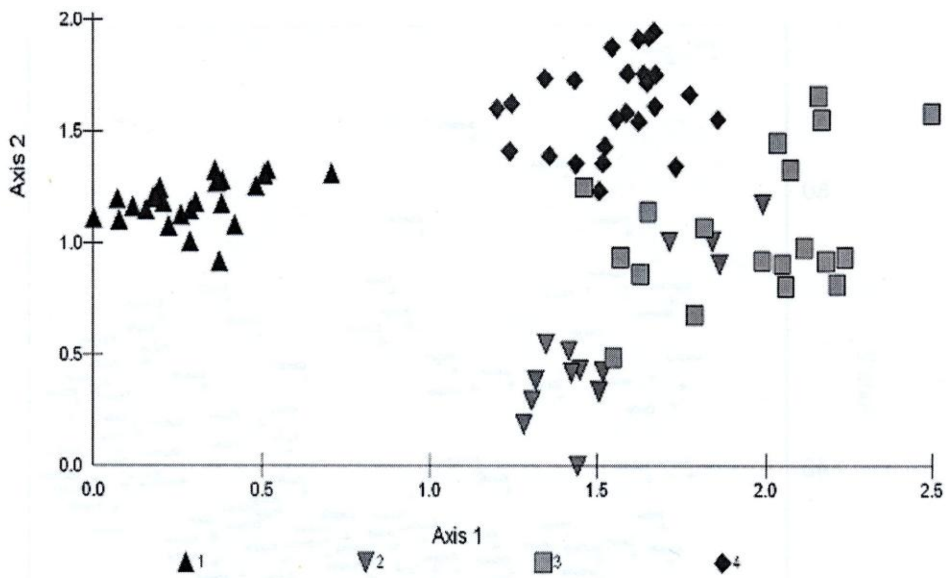

Fig. 3. DCA plot ordination overlaid with community types derived from TWINSPAN classification.

Legend

1 *Saccharum-Salix* community type
2 *Capparis-Eleusine* community type
3 *Prosopis-Chrysopogon* community type
4 *Ziziphus-Malcolmia* community type

Table 4. Eigenvalues and variation explained by DCA.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.36	0.17	0.10	0.07
Percentage variance explained	18.05	10.25	6.01	4.27
Cum. Percentage variance explained	18.05	28.31	34.32	38.60

Ordination of the species by DCA is given in Fig. 4. Species with high positive value on the DCA first axis are found mainly in the sites of the *Salix-Saccharum* community type. The species on the other end of the axis include *Capparis decidua, Cymbopogon schoenanthus, Eleusine compressa, Tamarix aphylla, Chrysopogon montanus* and *Justicia adhatoda*. These and many other species are commonly found in the *Capparis-Eleusine* community type. In the centre of the DCA diagram, there are many species which shared many vegetation types such as *Desmostachya bipinnata, Dalbergia sisso* and large number of herbaceous species and grasses. The distributions of species along the first axis indicate the soil moisture gradient. Along the DCA axis 2, species with the highest positive score include *Prosopis juliflora, Cenchrus ciliaris* and *Xanthium strumarium* and those belong to *Prosopis-Chrysopogon* community type whereas species at the other end of the axis are common in the *Capparis-Eleusine* and *Ziziphus-Malcolmia* vegetation types. The species trend along the second axis is not clear. However it seems that lots of factors are working together ranging from disturbances from biotic to edaphic factors.

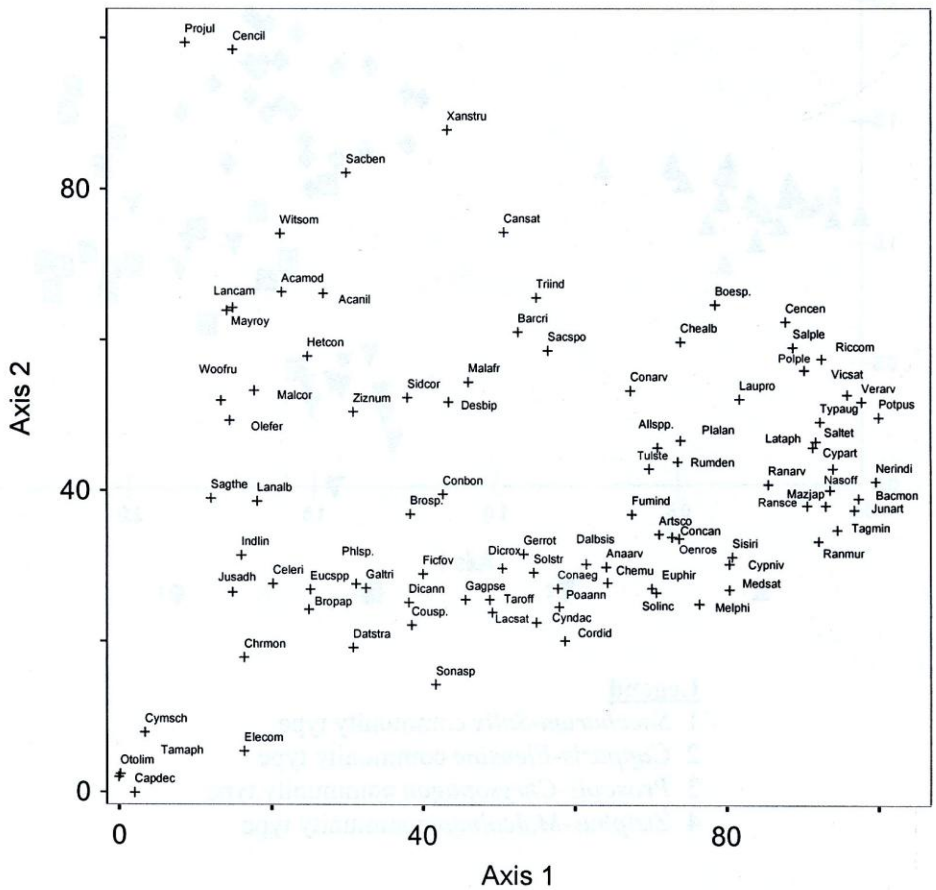

Fig. 4. DCA species ordination.

Discussion

Large numbers of studies have compared the results produced by applying different techniques of classification to the same data. Scudeller *et al.*, (2001) compared the results of cluster analysis and TWINSPAN for the classification of the ombrophilous dense forest in southeastern Brazil, Gauch & Whittaker (1981) compared a range of methods of similarity analysis with TWINSPAN and partition of ordination space. Both studies concluded that TWINSPAN gave better results. Although a large number of clustering algorithms for plant community classification are available (Legendre & Legenrde, 1998) these methods produce varying results on the same data set. This is due to the fact that these variations are dependent on the mathematical properties of each technique. But the best method is the one which enables a clear ecological interpretation for a particular purpose (Kent & Coker, 1992).

Plant community types

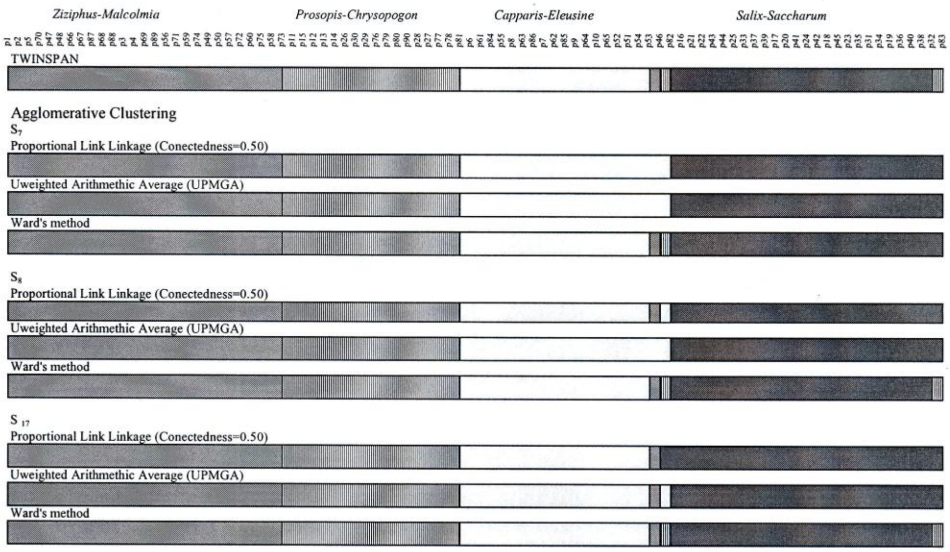

Fig. 5. Comparison of plant community types classified by TWINSPAN and agglomerative Clustering method

The results have indicated that the classification methods used in this study produce optimum groups. The TWINSPAN classification method produced vegetation groups at general levels whereas, using agglomerative clustering methods, sub-communities/groups could be separated within the major vegetation types. In general, vegetation community types were recognized using different clustering methods. Ward's method using different similarity indices gave slightly different results than proportional linkage and UPGMA, which gave similar results especially using S_7 and S_8 similarity indices. When different similarity indices were used, the Steinhaus (S_{17}) similarity index produced slightly different clusters from Sørensen's and Jaccard's similarity indices. This is possibly due to the fact that S_{17} was calculated using species abundance data (cover percentage) whereas Sørenson's and Jaccard's indices were calculated using binary data (presence and absence of species). As each similarity index measures different aspects of floristic similarity, some dissimilarity between the clusters they produced is to be expected. Most of the groups obtained from UPMGA, proportional link-linkage and Ward's methods using $S_{7,}$ S_8 and proportional link-linkage and Ward's method using S_{17} were quite similar to those produced from TWINSPAN. In general clusters defined by Ward's method were more similar to TWINSPAN classification, compared to clusters from other sorting strategies (Fig. 5).

Among the widely used ordination techniques for the plant community analysis Canonical Correspondence (CA) has shown to be superior to others such as PCA (Gauch, 1982). Most community data sets are heterogeneous and contain one or more gradients with lengths of at least two or three half-changes, which makes CA results ordinarily superior to PCA results. However, with relatively homogenous data sets with short gradients, PCA maybe better (Palmer, 1993). Despite the considerable superiority of the CA over PCA, CA is not superior to DCA, which corrects its two major faults such as "arch effect" and "compression of end of first axis" (Gauch, 1982; Kent & Coker, 1992). For complex and heterogeneous data sets, DCA is distinctive in its effectiveness and robustness (Gauch, 1982). Comparative tests of different indirect ordination techniques have shown that DCA provides a good result (Cazzier & Penny, 2002). This study found that DCA provides better results than CA results.

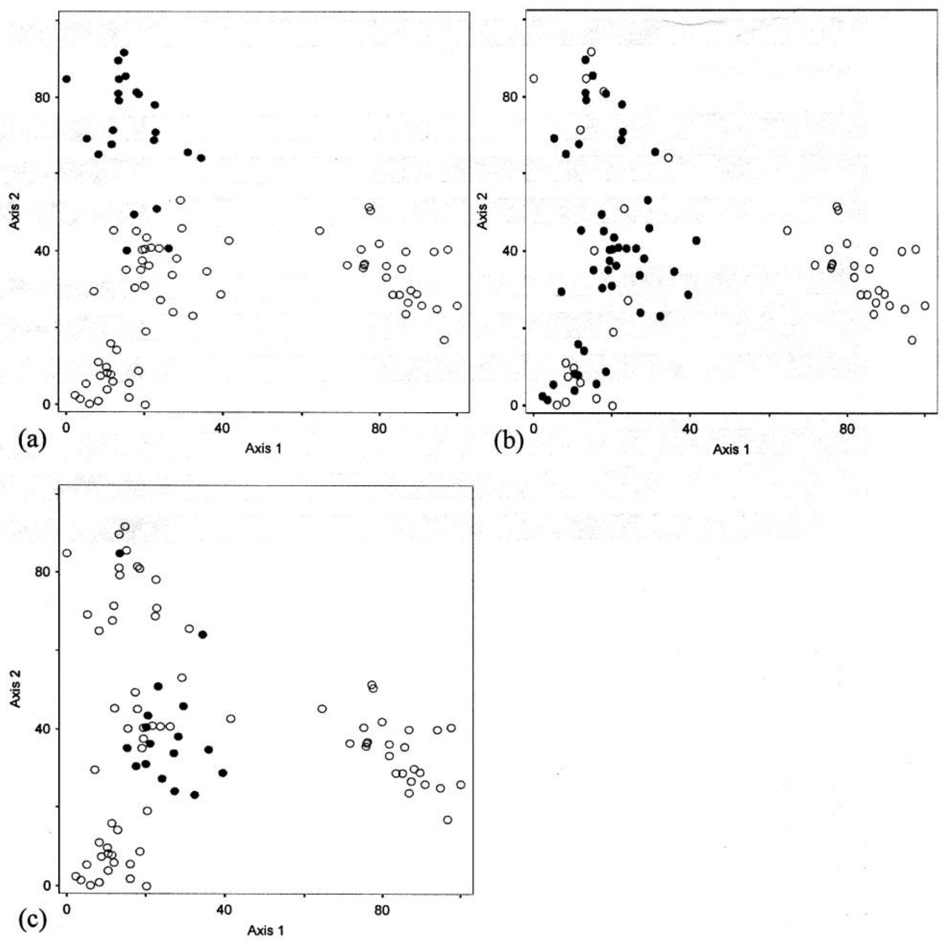

Fig. 6. Distribution of woody invasive plant species. Filled circles show their presence and unfilled show their absence in the field plots where (a) *Prosopis juliflora,* (b) *Lantana camara,* and (c) *Broussonetia papyrifera.*

Based on the results obtained from the ordination analyses, the species composition seems to be governed by a number of factors such as water table, soil texture and extent of flooding. For example the species composition of *Salix-Saccharum* seems to be more influenced by soil moisture and flooding than the other vegetation types because it was found on mesic sites whereas other vegetation types were observed on drier sites. The plots of *Salix-Saccharum* occupy the positive part of the axis and those of dense and degraded forest community types (such as *Prosopis-Chrysopogon* and *Capparis-Eleusine*) occupied the extreme negative part. Plant species, which also depict this trend, especially water-loving species were confined to the *Salix-Saccharum* community type. It is therefore suggested that these factors should be included as an important determinant of species composition in the community types in future investigations. It is also anticipated that the influence of these underlying environmental gradients needs to be analysed before community assemblages can be understood in detail. Therefore further studies should include these factors as an important underlying gradient in order to study the effects on the species distribution.

An invasion of *Broussonetia papyrifera, Lantana camara* and *Prosopis juliflora,* was observed (Fig. 6). It is anticipated that *Broussonetia papyrifer* could spread quickly, as maximum moisture is available for its growth and would possibly replace the remaining native vegetation of the scrub forest. *Lanatana camara* was observed in the *Capparis-Eleusine, Prosopis-Chrysopogon* and *Ziziphus-Malcolmia* community types. The first and only document presenting vegetation types of Pakistan by Champion *et al*., (1965) reported *Lantana camara* and *Prosopis juliflora* as invasive exotics with other listed species and that their spread may lead to different types of succession and even a different climax. According to them, large areas of the Punjab plains are being rapidly colonized by invasive exotics which are maintaining their ascendancy by regenerating profusely. There was no doubt that these species have come to stay and must now be taken into account as a permanent feature of the study area. It is clear from the results obtained that the entire vegetation of the study area is facing encroachment pressures, especially from grazing, cutting/felling, fuel and fodder consumption, and urbanization. These factors have contributed too much degradation of the vegetation and have influenced the species composition of many of the community types.

The study also demonstrated the potential of different classification and ordination analysis such as DCA in detecting the main environmental gradients and one could isolate a subset of environmental factors that led to a reasonable (ecologically meaningful) interpretation for important gradients in a few dimensions (Palmer, 1993).

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