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VEGETATION CLASSIFICATION OF THE MARGALLA FOOTHILLS, ISLAMABAD UNDER THE INFLUENCE OF EDAPHIC FACTORS AND ANTHROPOGENIC ACTIVITIES USING MODERN ECOLOGICAL TOOLS

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Abstract

The Margalla Hills falls in moist subtropical ecosystem with rich floristic diversity. Frequent field trips were conducted to record the floristic and ecological characteristics of vegetation. A total of 360 quadrats were laid down along 12 transects (8 on dry and 4 on the foothills' wet sites). Quadrat size was kept 10 x 10 m^2, 5 x 5 m^2 and 1x1 m^2 for trees, shrubs and herbs, respectively. Phytosociological attributes were determined for each plant species. Cluster, Two-way Cluster and Indicator Species Analyses of PCORD Version 5 were used to classify potential Landscape types and their respective indicators. Canonical Corresponding Analyses (CCA) and Detrented Corresponding Analyses (DCA) analyses were applied using CANOCO software to determine the significant effect of various environmental and edaphic variables on indicator species distribution patterns. Preliminary, a total of 187 plant species were recorded belong to 57 families. The topmost dominant families were Poaceae (27 species), followed by Leguminosae (17 species), Lamiaceae (11 species) and Moraceae (8 species). Therophytes (40%) followed by Phanerophytes (28%) were the region's dominant life forms. Microphylls leaf form was dominant (38%), followed by Mesophylls (30%). Six landscape types were identified after the Cluster Analysis with Sorenson distance measurements in the region. Environmental gradient analyses showed that the low potassium concentration, higher electrical conductivity, moderate organic matter, clay loam soil condition, anthropogenic activities, and grazing pressures significantly affect plant species distribution, composition, abundance, and different landscape type formation and their respective indicators.

Key words: Subtropical vegetation; Landscape; Indicators; Anthropogenic activities; Life form; Leaf spectra; Margalla foothill; Edaphic factors.

Introduction

Vegetation classification is the process by which vegetation is classified and mapped over an area of the earth's surface. It describes the distribution pattern, composition and diversity of plant species along with various climatic, edaphic factors and anthropogenic disturbances (Iqbal *et al*., 2017; Khan *et al*., 2017). It examines the existing vegetation structure and helps in the identification of different plant communities or habitat types (Ahmad *et al*., 2016). It describes different characteristics of plant species like physiognomic parameters, synthetic, analytic and quantitative characteristics in a definite way. Vegetation structure is determined or influenced by biotic and abiotic factors (Abbas *et al*., 2019; Anwar *et al*., 2019). Changes in biotic and abiotic factors might changes in other associated components as well.

Plant species richness and soil relationships have been studied in numerous habitats, including grassland, tropical communities and savanna rainforests (Khairil *et al*., 2014). In the field of plant ecology, the soil is recognised as one of the most important environmental factors. Soil chemical and physical properties have more impact on the vegetation distribution of any particular region (Rahman *et al*., 2016). For example, among macronutrients, nitrogen, potassium and phosphorus are essential to soil contents that assume their significant contributions in species-richness and occurrence (Awan *et al.,* 2021). Soil from various precursor materials has different reactions towards desertification, soil erosion and vegetation. The soil degradation rate relies upon vegetation degradation rate, which is also impacted by anthropogenic activities and climatic conditions. Shallow soil (e.g. limestone derivative) has dry moisture in its nature and has too slow recovery and vegetation growth. Besides these, the composition and pattern distribution of species usually has a variation on the slope which is best clarified by the accessibility of resources in which water availability has a key position (Badano *et al*., 2005; Gong *et al*., 2008).

The robust multivariate statistical software has facilitated data analysis like environmental and vegetation data in ecology. It helps the ecologists minimise the complexity in data set and organising structure (Ahmad *et al*., 2019; Ahmed *et al*., 2019). However, such studies regarding vegetation are rare (Malik & Husain, 2008; Khan *et al*., 2011; Iqbal *et al*., 2018). By using the indicator values and nature of the assemblage, plant species may be grouped. Usually, the assemblages are a mixture of species having restricted and wide ecological tolerance (Shah *et al*., 2015).

Little efforts have been made to provide a quantitative investigation of the landscape & habitat types along various ecological factors that accomplished their indispensable role in vegetation structure. Therefore, the current study was carried out to properly characterise vegetation, its classification into various landscape types under the impact of edaphic and other climatic variables in the Margalla foothills. It will also elaborate identification of indicator species by using the multivariate statistical approach.

Materials and Methods

Study site: Margalla hills falls in the territory of Himalayan foot hills, geographically and moist subtropical zone in floristic terms. It covers 31,100 hectares, spreading on the northern, eastern and western side of Islamabad, Pakistan. It has an elevation range from 450-1600m (Jabeen *et al*., 2009). These hills are predominantly covered by subtropical flora, mainly consisting of pine and semi-evergreen vegetation, while in recent periods, ornamental plants have been introduced in large numbers. This region's rock composition is limestone and comprising uneven topography (Mahmood *et al*., 2015). The overall climate is monsoonal, temperate and sub-humid. May and June were recorded as hottest months with a maximum mean temperature of 41°C. The mean relative humidity of this area fluctuates in the range of 59 to 67%.

Methods: An extensive phytosociological survey was carried out to explore the diversity of the vascular plants during 2016-17 in the Foothills of Margalla National Park, Islamabad, Pakistan. Transect and quadrat quantitative ecological techniques were used to sample vegetation (Noreen *et al*., 2019; Kamran *et al*., 2020; Manan *et al*., 2020). A total of 12 transects were laid down, 4 on wetland along streams side while the remaining 8 were taken on the research area's dry land. 360 quadrats (30 at each transect) were taken for trees, shrubs and herbs, respectively. Size of the quadrats was $1\times1m^2$, $5\times5m^2$ and $10\times10m^2$ for herbs, shrubs and trees, respectively (Hussain *et al*., 2019; Khan *et al*., 2020). Phytosociological attributes, i.e., density, relative density, frequency, relative frequency, cover, relative cover and Important Values were measured for each of the plant species at each quadrat. The tree species diameters were measured at breast height using the formula, Basal Area = [(DBH/2) 2 x 3.143 or πr^2]. Specimens were collected from the respective site. Furthermore, unidentified plant species were appropriately tagged. All the collected specimens were shad dried and mounted on standard herbarium sheets with complete information. Plants were identified according to the Flora of Pakistan (Ali & Qaiser, 2004) and other available literature (Nasir *et al*., 1972; Stewart, 1972). Longitude, latitude and elevation were measured using Geographical Positioning System at each quadrat.

Soil Analyses: Soil samples were collected randomly at a depth of 0.3m from four different sites within quadrats, then adequately mixed and this bulk was considered a single sample. These samples were air-dried and analysed for various parameters like pH, electrical conductivity (EC), organic matter, Soil texture, potassium and phosphorus. The protocols which were used for the concentration level of Nitrogen as per (Bremner *et al*., 1996), pH and electrical conductivity according to (Rhoades & Miyamoto, 1990), Potassium and Phosphorus as per (Soltanpour, 1985), Organic Matter by (Nelson & Sommers, 1996) and soil texture by simple feel sieve method.

Data Preparation and Analyses: Data was put and arranged in Microsoft Excel 2010 according to PCORD and CANOCO software requirements in order to compute further analysis. Multivariate statistical techniques were applied for data analysis that included Cluster analysis (CA), Two-way Cluster Analysis (TWCA), Indicator Species Analysis (ISA), Canonical Correspondence Analysis (CCA) and Detrended Correspondence Analysis (DCA) via PCORD and CANOCO software, respectively (Khan *et al*., 2013; Bano *et al*., 2018).

Results

A total of 187 plant species were recorded belonging to 57 families from the study site. Out of which, 62 plants were trees, 23 shrubs and 102 herbs. Angiosperms, Gymnosperms and Pteridophyte families were reported from the Margalla Foothills, Islamabad, Pakistan. Angiosperm families were further divided into monocotyledonous (3 in number; Araceae, Cyperaceae and Poaceae) and dicotyledonous (49 in number). Among the remaining 6 families, 3 families belong to Gymnosperm i.e., Araucariaceae, Cupressaceae & Pinaceae and 2 belongs to Pteridophytes i.e., Equisetaceae and Pteridaceae. Family Poaceae was the topmost dominant family (with 14.43% share of the total vegetation) followed by Leguminosae. Therophytes were the dominant life form (73 species), followed by phanerophytes and chamaephytes. Microphylls with 71 species were the dominant leaf form, followed by mesophylls with 56 species (Appendix table 1).

Species Distribution: TWCA showed the detailed species distribution of all the recorded plant species in the region. The black and white dots represent the presence and absence of plant species, respectively (Fig. 1).

Classification of plant species into potential habitat types: All the collected plant species and station data were analysed through PCORD software that classified them into six potential Landscape/habitat types (Fig. 2). Furthermore, indicator species of each habit were identified using ISA.

Appendix table 1. List of recorded plant species along with their leaf spectra, life form and habit.

Family	Botanical Names	Group	Leaf spectra	Life form	Habit
Acanthaceae	*Adhatoda vasica* Nees	Angiosperm	Mic	Np	Shrub
	Dicliptera bupleuroides Nees	Angiosperm	Mes	Th	Herb
Aizoaceae	*Trianthema portulacastrum* L.	Angiosperm	Nan	Th	Herb
Amaranthaceae	*Alternanthera pungens* Kunth	Angiosperm	Mic	Th	Herb
	Amaranthus viridis L.	Angiosperm	Mic	Th	Herb
	Chenopodium album L.	Angiosperm	Mic	Th	Herb
	Digera muricata (L.) Mart.	Angiosperm	Mic	Th	Herb
	Dysphania ambrosioides (L.) Mosyakin & Clemants	Angiosperm	Mic	Th	Herb
Anacardiaceae	*Mangifera indica* L.	Angiosperm	Mes	Ph	Tree
	Pistacia chinensis Bunge	Angiosperm	Mes	Ch	Tree
Apocynaceae	*Alstonia scholaris* (L.) R. Br.	Angiosperm	Mes	Ph	Tree
	Nerium oleander L.	Angiosperm	Mic	Np	Tree
	Thevetia peruviana (Pers.) K.Schum.	Angiosperm	Mic	Ph	Tree
	Calotropis procera (Aiton) Dryand.	Angiosperm	Mes	Ch	Shrub
	Carissa opaca Stapf ex Haines	Angiosperm	Mic	Th	Shrub
	Nerium oleander L.	Angiosperm	Nan	Np	Shrub
	Periploca aphylla Decne.	Angiosperm	L	Np	Shrub
Araucariaceae	*Araucaria columnaris* (G. Forst.) Hook.	Angiosperm	Na	Ph	Tree
Arecaceae	*Livistona chinensis* (Jacq.) R.Br. ex Mart.	Angiosperm	Meg	Ph	Tree
	Phoenix dactylifera L.	Angiosperm	Mes	Th	Tree
	Phoenix sylvestris (L.) Roxb.	Angiosperm	Mes	Cr	Tree
Asparagaceae	*Agave Americana* L.	Angiosperm	Mic	Th	Shrub
	Agave veracrose L.	Angiosperm	Mic	Th	Shrub
Asparagaceae	*Asparagus capitatus* Baker	Angiosperm	Lp	Ch	Herb
	Asparagus gracilis Salisb.	Angiosperm	Lp	Ch	Herb
	Asparagus officinalis L.	Angiosperm	Lp	Ch	Herb
Asteraceae	*Bidens pilosa* (L.) DC.	Angiosperm	Mic	Th	Herb
	Erigeron bonariensis (L.)	Angiosperm	Nan	Th	Herb
	Erigeron canadensis (L.)	Angiosperm	Nan	Th	Herb
Bignoniaceae	*Jacaranda mimosifolia* D.Don	Angiosperm	Mes	Ph	Tree
	Tecoma stans (L.) Juss. ex Kunth	Angiosperm	Mes	Ph	Tree
Boraginaceae	*Ehretia obtusifolia* Hochst. ex A.DC.	Angiosperm	Mes	Ph	Tree
	Cynoglossum lanceolatum Forssk.	Angiosperm	Nan	Hc	Herb
	Heliotropium strigosum Willd.	Angiosperm	Mic	Th	Herb
	Trichodesma indicum (L.) Lehm.	Angiosperm	Nan	Th	Herb
Brassicaceae	*Eruca sativa* Mill.	Angiosperm	Mic	Th	Herb
Buxaceae	*Buxus papillosa* C.K.Schneid.	Angiosperm	Mic	Mp	Shrub
Cactaceae	*Cactus dillenii* Ker Gawl.	Angiosperm	Mes	Ch	Shrub
Cannabaceae	*Celtis eriocarpa* Decne.	Angiosperm	Mes	Ph	Tree
	Celtis australis L.	Angiosperm	Mes	Ph	Tree
	Cannabis sativa L.	Angiosperm	Mic	H	Herb
Caryophyllaceae	*Spergula arvensis* L.	Angiosperm	Nan	Th	Herb
Celastraceae	*Gymnospermsporia royleana* Wall. ex M.A. Lawson	Angiosperm	Mic	Ch	Shrub
Cannaceae	*Canna indica* L.	Angiosperm	Mac	Th	Herb
Cleomaceae	*Cleome viscosa* L.	Angiosperm	Mes	Ch	Herb
Commelinaceae	*Commelina benghalensis* L.	Angiosperm	Mic	Th	Herb
Compositae	*Centaurea iberica* Trevir. ex Spreng.	Angiosperm	Nan	Th	Herb
	Echinops echinatus Roxb.	Angiosperm	Mic	Th	Herb
	Parthenium hysterophorus L.	Angiosperm	Mes	Th	Herb
	Sonchus asper (L.) Hill	Angiosperm	Mes	Th	Herb
	Sonchus oleraceus (L.) L.	Angiosperm	Mes	Th	Herb
Convolvulaceae	*Convolvulus arvensis* L.	Angiosperm	Mes	Th	Herb
Cupressaceae	*Cupressus sempervirens* L.	Gymnosperm	Lp	Ph	Tree
	Thuja orientalis L.	Gymnosperm	Mic	Np	Shrub
Cyperaceae	*Cyperus niveus* Retz.	Angiosperm	Nan	Cr	Herb
	Cyperus rotundus L.	Angiosperm	Nan	Cr	Herb
	Erioscirpus comosus (Wall.) Palla	Angiosperm	Lp	Cr	Herb
Equisetaceae	*Equisetum arvense* L.	Pteridophytes	Lp	Cr	Herb
Euphorbiaceae	*Sapium sebiferum* (L.) Roxb.	Angiosperm	Mic	Ph	Tree
	Ricinus communis L.	Angiosperm	Nan	Th	Shrub
	Chrozophora tinctoria (L.) A.Juss.	Angiosperm	Mes	Ch	Herb
	Croton bonplandianus Baill.	Angiosperm	mic	Ch	Herb
	Euphorbia hirta L.	Angiosperm	Nan	Th	Herb
	Euphorbia indica Lam.	Angiosperm	Nan	Th	Herb

Appendix table 1. (Cont'd.)..

Family	Botanical Names	Group	Leaf spectra	Life form	Habit
Fabaceae	*Sophora japonica* L.	Angiosperm	Mic	Ph	Tree
	Mentha arvensis L.	Angiosperm	Mic	Th	Herb
	Mentha longifolia (L.) L.	Angiosperm	Mic	Th	Herb
	Mentha royleana Wall. ex Benth.	Angiosperm	Mic	Th	Herb
	Colebrookea oppositifolia Sm.	Angiosperm	Mic	Np	Tree
	Vitex negundo L.	Angiosperm	Mic	Np	Tree
Lamiaceae	*Otostegia limbata* (Benth.) Boiss.	Angiosperm	Nan	Np	Shrub
	Ajuga bracteosa Wall. ex Benth.	Angiosperm	Mic	Th	Herb
	Anisomeles indica (L.) Kuntze	Angiosperm	Mic	Hc	Herb
	Clinopodium umbrosum (M.Bieb.) Kuntze	Angiosperm	Mic	Th	Herb
	Lycopus europaeus L.	Angiosperm	Mes	Ch	Herb
	Micromeria biflora (Buch.-Ham. ex D.Don) Benth.	Angiosperm	Mic	Th	Herb
	Acacia modesta Wall.	Angiosperm	Lp	Ph	Tree
	Acacia nilotica (L.) Delile	Angiosperm	Lp	Ph	Tree
	Albizia lebbeck (L.) Benth.	Angiosperm	Lp	Ph	Tree
	Bauhinia variegata L.	Angiosperm	Mes	Ph	Tree
	Cassia fistula L.	Angiosperm	Mes	Ph	Tree
	Dalbergia sissoo DC.	Angiosperm	Mic	Ph	Tree
	Erythrina suberosa Roxb.	Angiosperm	Mic	Ph	Tree
	Mimosa hamate Willd.	Angiosperm	Lp	Np	Tree
Leguminosae	*Pongamia pinnata* (L.) Pierre	Angiosperm	Mes	Ph	Tree
	Robinia pseudoacacia L.	Angiosperm	Mic	Np	Tree
	Astragalus aaronii (Eig) Zohary	Angiosperm	Mic	Ch	Herb
	Crotalaria medicaginea Lam.	Angiosperm	Np	Th	Herb
	Desmodium gangeticum (L.) DC.	Angiosperm	Mic	Th	Herb
	Lespedeza juncea (L.f.) Pers	Angiosperm	Mic	Th	Herb
	Melilotus officinalis (Medik.)	Angiosperm	Nan	Th	Herb
	Rhynchosia capitata (Roth) DC.	Angiosperm	Mic	Cr	Herb
	Rhynchosia minima (L.) DC.	Angiosperm	Mic	Cr	Herb
Lythraceae	*Punica granatum* L.	Angiosperm	Na	Ph	Tree
	Lagerstroemia indica L.	Angiosperm	Mes	Ph	Shrub
Malvaceae	*Bombax ceiba* L.	Angiosperm	Mes	Ph	Tree
	Pterospermum acerifolium (L.) Willd.	Angiosperm	Mes	Ph	Tree
	Sterculia diversifolia Seem.	Angiosperm	Mes	Ph	Tree
	Corchorus tridens L.	Angiosperm	Nan	Ch	Herb
	Malvastrum coromandelianum (L.) Garcke	Angiosperm	Mic	Hc	Herb
	Sida cordata (Burm.f.) Borss. Waalk.	Angiosperm	Mic	Th	Herb
Meliaceae	*Cedrela toona* Roxb. ex Rottler	Angiosperm	Mes	Ph	Tree
	Melia azedarach L.	Angiosperm	Mic	Ph	Tree
Moraceae	*Broussonetia papyrifera* (L.) L'Hér. ex Vent.	Angiosperm	Mes	Ph	Tree
	Ficus elastic Roxb. ex Hornem.	Angiosperm	Mes	Ph	Tree
	Ficus lacor Buch.-Ham.	Angiosperm	Mes	Ph	Tree
	Ficus palmate Forssk.	Angiosperm	Mes	Ph	Tree
	Ficus racemosa L.	Angiosperm	Mes	Ph	Tree
	Ficus religiosa L.	Angiosperm	Mes	Ph	Tree
	Morus alba L.	Angiosperm	Mes	Ph	Tree
	Morus nigra L.	Angiosperm	Mes	Ph	Tree
Myrtaceae	Callistemon citrinus (cutis) skeels	Angiosperm	mic	Ph	Tree
	Eucalyptus camaldulensis Dehnh.	Angiosperm	Na	Th	Tree
	Eugenia jambolana Lam.	Angiosperm	Mes	Ph	Tree
	Syzgium cummuni (L.)Skeels	Angiosperm	Mes	Ph	Tree
Nyctaginaceae	*Bougainvillea spectabilis* Willd.	Angiosperm	Mes	Ch	Shrub
	Boerhavia procumbens Banks ex Roxb.	Angiosperm	Nan	Th	Herb
Oleaceae	*Olea ferruginea* Wall. ex Aitch.	Angiosperm	Mic	Ph	Tree
Onagraceae	*Oenothera rosea* L'Hér. ex Aiton	Angiosperm	Mic	Th	Herb
Oxalidaceae	*Oxalis corniculata* L.	Angiosperm	Mic	Th	Herb
Pedaliaceae	*Sesamum indicum* L.	Angiosperm	Mic	Th	Herb
Pinaceae	*Pinus roxburghii* Sarg.	Gymnosperm	Lp	Ph	Tree
Plantaginaceae	*Bacopa monnieri* (L.) Wettst.	Angiosperm	Nan	Th	Herb

Appendix table 1. (Cont'd.)..

Family	Botanical Names	Group	Leaf spectra	Life form	Habit
	Arundo dona L.	Angiosperm	Mes	Hc	Herb
	Brachiaria eruciformis (Sm.) Griseb.	Angiosperm	Mac	Th	Herb
	Brachiaria ramose (L.) Stapf	Angiosperm	Mac	Th	Herb
	Brachiaria reptans (L.) C.A.Gardner & C.E.Hubb.	Angiosperm	Mac	Th	Herb
	Briza minor L.	Angiosperm	Mic	Th	Herb
	Chrysopogon serrulatus Trin.	Angiosperm	Mic	Th	Herb
	Cymbopogon citratus (DC.) Stapf	Angiosperm	Nan	Ch	Herb
	Cymbopogon distans (Nees ex Steud.) W.Watson	Angiosperm	Nan	Ch	Herb
	Cymbopogon jwarancusa (Jones) Schult.	Angiosperm	Nan	Ch	Herb
	Cynodon dactylon (L.) Pers.	Angiosperm	Lp	Hc	Herb
	Dactyloctenium aegyptium (L.) Willd.	Angiosperm	Nan	Th	Herb
	Desmostachya bipinnata (L.) Stapf	Angiosperm	Mic	Th	Herb
	Dichanthium annulatum (Forssk.) Stapf	Angiosperm	Mic	Th	Herb
Poaceae	*Digitaria ciliaris* (Retz.) Koeler	Angiosperm	Na	Th	Herb
	Eleusine indica (L.) Gaertn.	Angiosperm	Nan	Th	Herb
	Hemarthria compressa (L.f.) R.Br.	Angiosperm	Lep	Th	Herb
	Imperata cylindrical (L.) Raeusch.	Angiosperm	Lp	Hc	Herb
	Leptochloa chinensis (L.) Nees	Angiosperm	Nan	Th	Herb
	Paspalidium flavidum (Retz.) A.Camus	Angiosperm	Nan	Th	Herb
	Paspalum paspalodes (Michx.) Scribn.	Angiosperm	Nan	Th	Herb
	Poa annua L.	Angiosperm	Lp	Th	Herb
	Saccharum bengalense Retz.	Angiosperm	Mic	Hc	Herb
	Saccharum griffithii Munro ex Aitch.	Angiosperm	Mac	Th	Herb
	Saccharum arundinaceum Retz	Angiosperm	Mes	Th	Herb
	Cymbopogon distans (Nees ex Steud.) W.Watson	Angiosperm	Mes	Th	Herb
	Setaria pumila (Poir.) Roem. & Schult.	Angiosperm	Nan	Hc	Herb
	Setaria viridis (L.) P.Beauv.	Angiosperm	Nan	Hc	Herb
	Polygala abyssinica R.Br. ex Fresen.	Angiosperm	Mic	Th	Herb
	Polygala arvensis Willd.	Angiosperm	Mic	Th	Herb
Polygalaceae	*Polygala erioptera* DC.	Angiosperm	Nan	Th	Herb
	Persicaria glabra (Willd.) M. Gómez	Angiosperm	Mes	Cr	Herb
	Persicaria hydropiper (L.) Delarbre	Angiosperm	Mes	Cr	Herb
Primulaceae	*Myrsine africana* L.	Angiosperm	Nan	Np	Shrub
Proteaceae	*Grevillea robusta* A.Cunn. ex R.Br.	Angiosperm	Mes	Ph	Tree
Pteridaceae	*Adiantum incisum* Forssk.	Pteridophytes	Na	Cr	Herb
Putranjivaceae	*Putranjiva roxburghii* Wall.	Angiosperm	MIc	Ph	Tree
	Ziziphus spina-christi (L.) Desf.	Angiosperm	Mic	Np	Tree
Rhamnaceae	*Ziziphus mauritiana* Lam.	Angiosperm	Mic	Np	Tree
	Ziziphus nummularia (Burm.f.) Wight & Arn.	Angiosperm	Mic	Np	Tree
	Sageretia thea (Osbeck) M.C. Johnst.	Angiosperm	Mic	Ch	Shrub
Rosaceae	*Prunus armeniaca* L.	Angiosperm	Mic	Ph	Tree
Rubiaceae	*Rubia cordifolia* L.	Angiosperm	Mic	Hc	Herb
	Citrus limon (L.) Osbeck	Angiosperm	Mes	Ph	Tree
Rutaceae	*Citrus medica* L.	Angiosperm	Mes	Ph	Tree
	Zanthoxylum stramoniuml L.	Angiosperm	Mes	Th	Herb
	Zanthoxylum spinosum (L.) Sw.	Angiosperm	Mes	Th	Herb
	Populus alba L.	Angiosperm	Mes	Ph	Tree
Salicaceae	*Populus ciliata* Wall. ex Royle	Angiosperm	Mes	Ph	Tree
	Salix acmophylla Boiss.	Angiosperm	Mes	Ph	Tree
Sapindaceae	*Dodonaea viscosa* (L.) Jacq.	Angiosperm	Mic	Np	Shrub
Simaroubaceae	*Ailanthus altissima* (Mill.) Swingle	Angiosperm	Mes	Ph	Tree
	Datura stramonium L.	Angiosperm	Mes	Np	Shrub
Solanaceae	*Jasminoides himalaya* L.	Angiosperm	Mic	Ch	Shrub
	Solanum nigrum L.	Angiosperm	Mic	Th	Herb
	Solanum abancayense Ochoa	Angiosperm	Mic	Th	Herb
	Citharexylum spinosum L.	Angiosperm	Mic	Ph	Tree
	Duranta repens L.	Angiosperm	Mic	Ch	Shrub
Verbenaceae	*Lantana camara* L.	Angiosperm	Mic	Np	Shrub
	Phyla nodiflora (L.) Greene	Angiosperm	Mic	Cr	Herb
	Verbena officinalis L.	Angiosperm	Mic	Th	Herb
	Verbena tenuisecta Briq.	Angiosperm	Mic	Th	Herb
Xanthorrhoeaceae	*Aloe vera* (L.) Burm.f.	Angiosperm	Mic	Np	Shrub
Zygophyllaceae	*Fagonia indica* Burm.f.	Angiosperm	Lep	Hc	Herb
	Tribulus terrestris L.	Angiosperm	Nan	Th	Herb

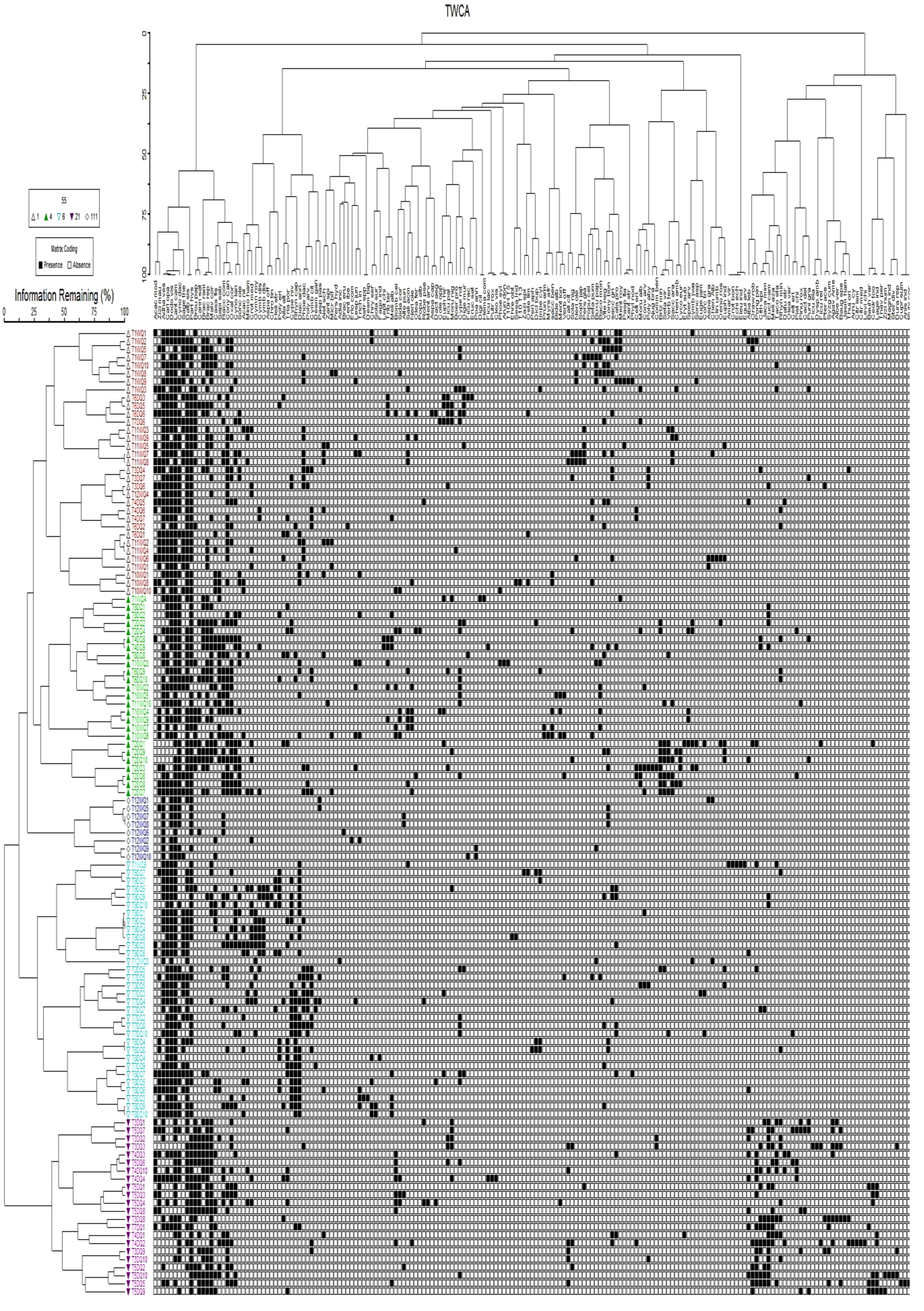

Fig. 1. Two-way Cluster Analysis dendrogram showing the distribution of plant species in all quadrats/stations.

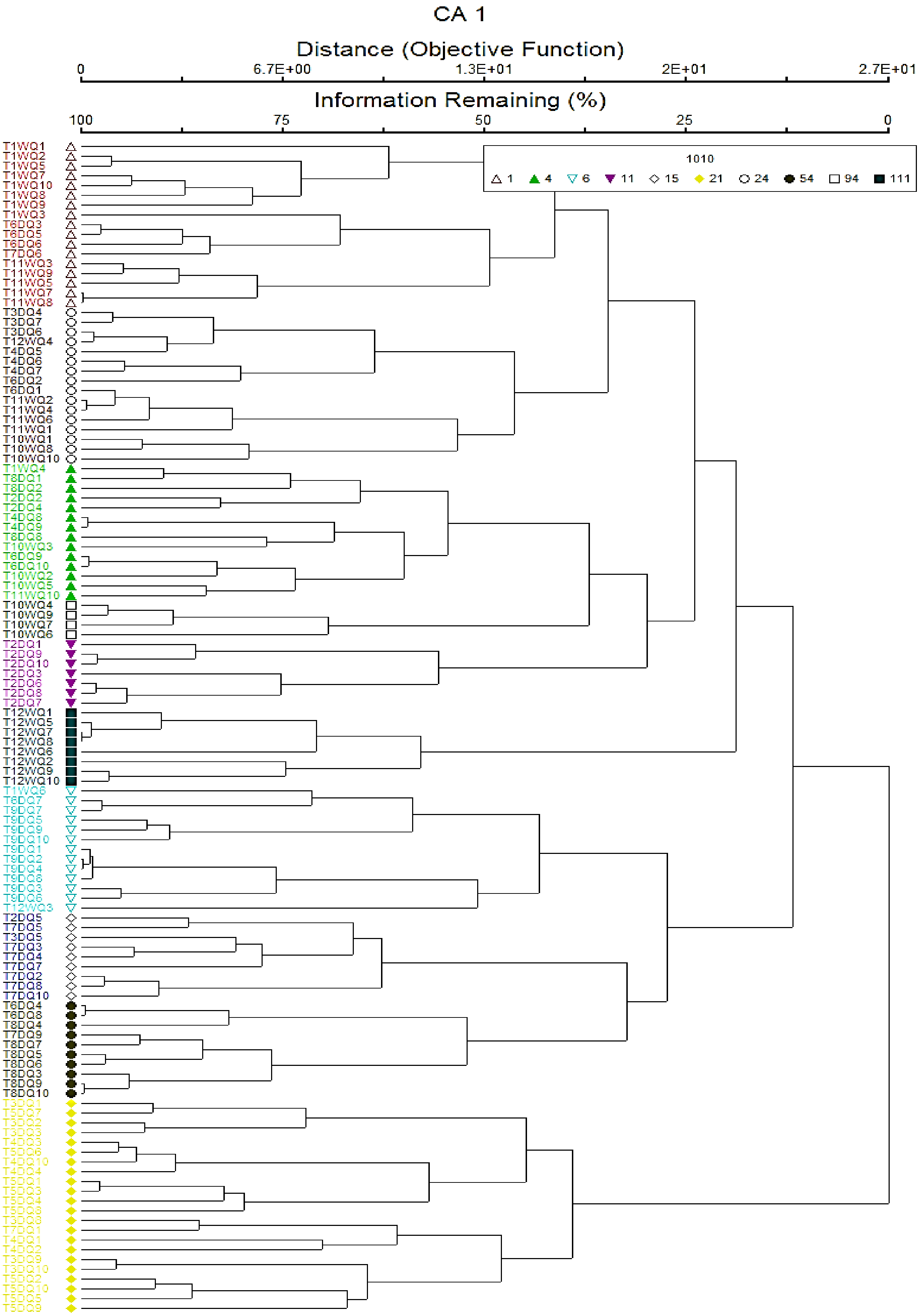

Fig. 2. Cluster dendrogram classifying all the stations into 6 Landscape types.

1) Landscape type 1: *Phoenix dactylifera-Lantana camara-Bacopa monieri habitat*: This Landscape type estacbishes on wet habitat, comprises 17 quadrats/stations using Sorenson measurements. Characteristics species of this Landscape type were *Phoenix dactylifera, Lantana camara* and *Bacopa monieri* as a tree, shrub and herb, respectively (Fig. 3). Low organic matter, electrical conductivity and sandy clay loam soil texture were the influencing variables of this habitat type compared to others (Table 1). Furthermore, *Ficus racemosa, Ficus palmata*, and *Vitex negundo* were dominant, while *Albizia lebbeck, Acacia nilotica*, *Olea ferruginea* and *Salix acmophylla* were the rare tree species of this Landscape type based on IVI values. Similarly, the dominant shrubs included *Carissa opaca,* while rare shrubs were *Otostegia limbata*, *Calotropis procera* and *Buxus papillosa*. The dominant herbaceous layer revealed *Cynodon dactylon*, *Brachiaria reptans* and *Oxalis carniculata* while rare herb species were *Verbena tenuisecta*, *Sida cordata*, *Imperata cylindrica* and *Equisetum arvensis* with minimum IVI in the region. This landscape is mainly formed on the soil with texture loam, clay loam, sandy clay loam and silty clay loam having pH ranged from 6.6 to 7.3, which is approximately neutral. The EC of this landscape ranged from 0.165 to 1.654 ds/m, organic matter varies 0.53 to 0.77%, Phosphorus ranges 4 to 7 ppm, Potash from 84 to 89 ppm, nitrogen level from 0.004 to 0.002% and soil pH ambit from 6.5 to 7.5 in the region.

2) Landscape type 2: *Acacia modesta- Thuja orientalis-Erigeron Canadensis habitat:* This Landscape type comprises 16 quadrats. *Acacia modesta, Thuja orientalis* and *Erigeron Canadensis* were the topmost indicator species of this landscape type (Fig. 4). Some of this landscape's stations were assembled on the streamside (Wetland), while some fell on dry areas. High Anthropogenic activities and high grazing pressure were the significant variables that shape vegetation of this landscape type (Table 1).

Cassia fistula was the dominant and *Punica granatum*, *Pterospermum acerifolium* and *Phoenix sylvestris* were the rare tree species of this region. Furthermore, the dominant shrub was *Adhatoda vasica,* while rare shrub species were *Otostegia limbata, Lagerstroemia indica* and *Datura stramonium*. As in the same case, the dominant herbs were *Cynodon dactylon* and *Oxalis corniculata* while rare herb species included *Euphorbia indica*, *Oenothera rosea*, *Solanum nigrum*, *Xanthium spinosum, Cynoglossum lanceolatum* and *Sesamum Indicum*. This landscape is mainly developed on the soil with texture loam, sandy clay loam and silty clay loam having pH range from 6.7 to 7.2, EC 0.235 to 1.694 ds/m, organic matter 0.52 to 0.71%, Phosphorus 4 to 8 ppm, Potash (K) range from 73 to 101 ppm and nitrogen level from 0.002 to 0.012%.

3) Landscape type 3: *Dalbergia sissoo - Ricinus communis - Parthenium hysterophorus habitat:* This Landscape included 33 quadrats. *Dalbergia sissoo, Ricinus communis* and *Parthenium hysterophorus* were the main indicator species of this landscape type which were recognised based on high anthropogenic activities, a moderate amount of Potassium and high electrical conductivity in the region (Fig. 5; Table 1). The top dominant tree species of this landscape type were *Sapium sebiferum* and *Cassia fistula,* whereas the rare tree species were *Colebrookea oppositifolia*, *Ficus religiosa*, *Grevillea robusta* and *Pinus roxburghii*. In the shrubs' dominancy, the top dominant species was *Adhatoda vesica*, while rare shrubs were *Calotropis procera*, *Buxus papillosa* and *Myrsine africana*. *Cynodon dactylon*, *Oxalis corniculata*, *Briza minor* and *Brachiaria ramosa* were abundant herbs, whereas *Xanthium spinosum*, *Ajuga bracteosa*, *Commelina benghalensis*, *Bidens alba* and *Asparagus gracilis* were the rare herb species of this landscape type.

This habitat's stand consisted of dry and wet areas. It was also disturbed by anthropogenic pressure due to roads, building and construction activities. This landscape is mainly developed on the soil with texture loam, sandy clay loam, clay loam and silty clay loam having pH ranged from 6.5 to 7.4. The EC of this landscape ranged from 0.225 to 1.682 ds/m, organic matter ranged from 0.53 to 0.76%, Phosphorus (P) ranged from 3 to 8 ppm, Potash (K) range from 76 to 110 ppm and nitrogen level from 0.025–0.022%.

4) Landscape type 4: *Eucalyptus camaldulensis-Dodonaea viscosa-Diacanthium annulatum habitat*: This Landscape type is comprised of 13 quadrats. The topmost characteristics species were *Eucalyptus camaldulensis, Dodonaea viscosa* and *Diacanthium annulatum* correlated with high anthropogenic activity, silty clay loam soil texture and high EC, respectively (Fig. 6; Table 1). The topmost dominant tree species of this Landscape type were *Vitex negundo* and *Cassia fistula* whereas *Ziziphus spina Christi, Tecoma stans* and *Pongamia pinnata* were the rare tree species. *Adhatoda vasica*, *Otostegia limbata* and *Calotropis procera* were the dominant and rare shrub species of this landscape type. Dominant herb species were *Oxalis corniculata and Cymbopogon distans,* whereas rare herb species were *Convolvulus arvensis, Chrozophora tinctoria, Chenopodium Album* and *Sesamum indicum*. This landscape is mainly developed on the soil with texture loam, clay loam and silty clay loam having pH ranged from 6.7 to 7.2. The EC of this landscape ranged from 0.668 to 1.584 ds/m, organic matter 0.54 to 0.73%, Phosphorus 4 to 8 ppm, Potash 78 to 114 ppm and nitrogen level from 0.036–0.012%.

5) Landscape type 5: *Zizyphus mauritiana-Carissa opaca -Cyperus niveus habitat:* A total of 19 stations were included in this landscape type. The topmost indicator species of this landscape type were *Zizyphus mauritiana*, *Carissa opaca* and *Cyperus niveus*. The environmental variables associated with these indicator species were low potassium concentration, moderate organic matters, high electrical conductivity and silty clay loam soil texture (Fig. 7; Table 1). The dominant and rare tree species of this landscape type were *Robinia pseudoacacia, Pongamia pinnata* and *Jacaranda mimosifolia*. *Adhatoda vasica* was dominant while *Periploca aphylla*, *Calotropis procera* and *Gymnosporia royleana* were the rare shrub species in the region. This landscape is mainly developed on the soil with texture loam, clay loam, sandy clay loam and silty clay loam having pH range from 6.6 to 7.2. The EC of this landscape ranged from 0.332 to 1.422 ds/m, organic matter 0.53 to 0.83%, Phosphorus 4 to 8 ppm, Potash 73 to 109 ppm and nitrogen level from 0.023–0.013%.

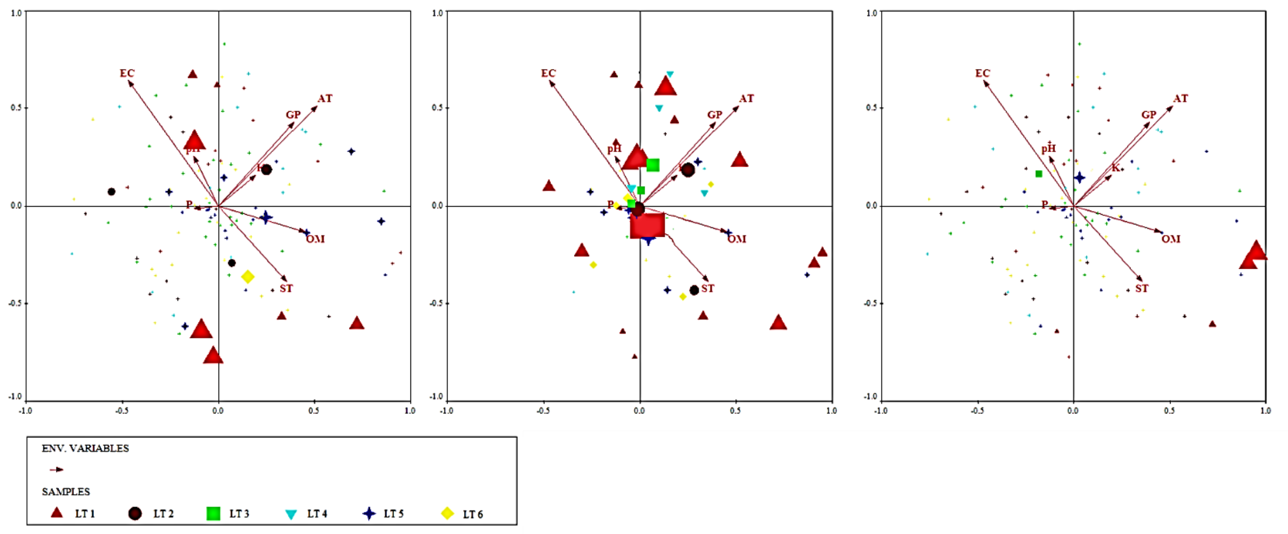

Fig. 3. CCA data attribute plot of topmost indicator species of Landscape type-1.

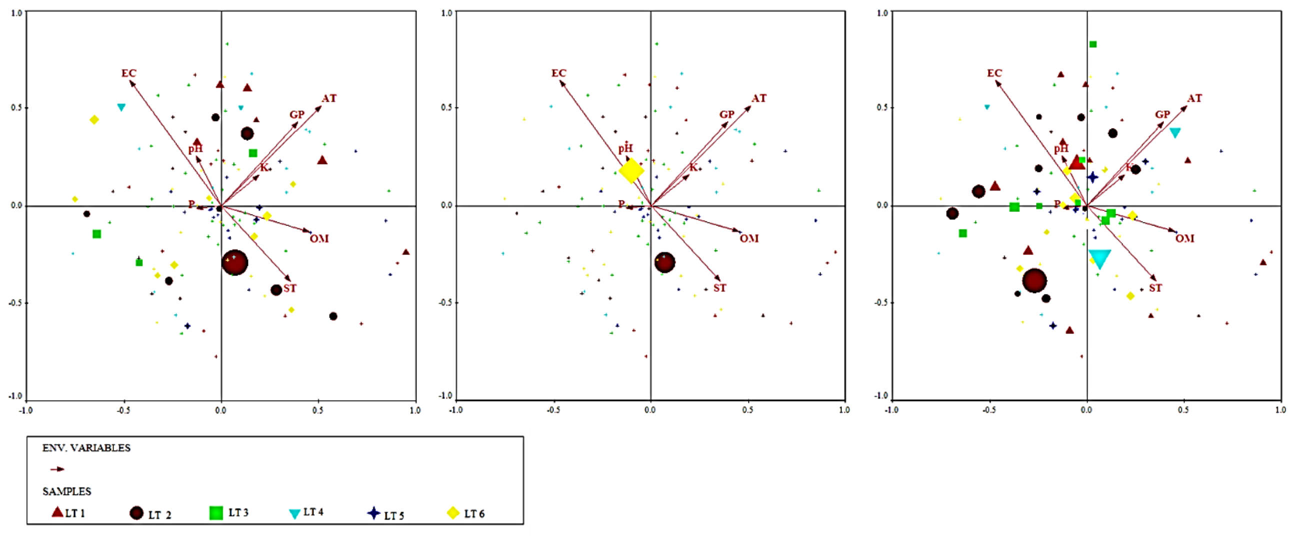

Fig. 4. CCA data attribute plot of topmost three indicator species of Landscape type-2.

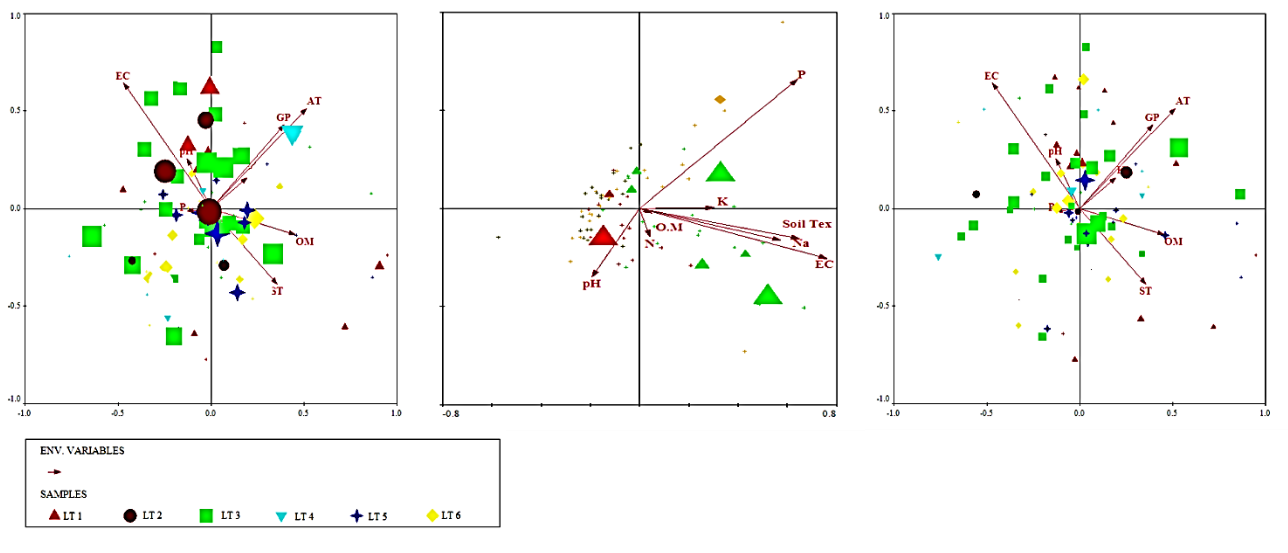

Fig. 5. CCA data attribute plot of indicator species of Landscape type-3.

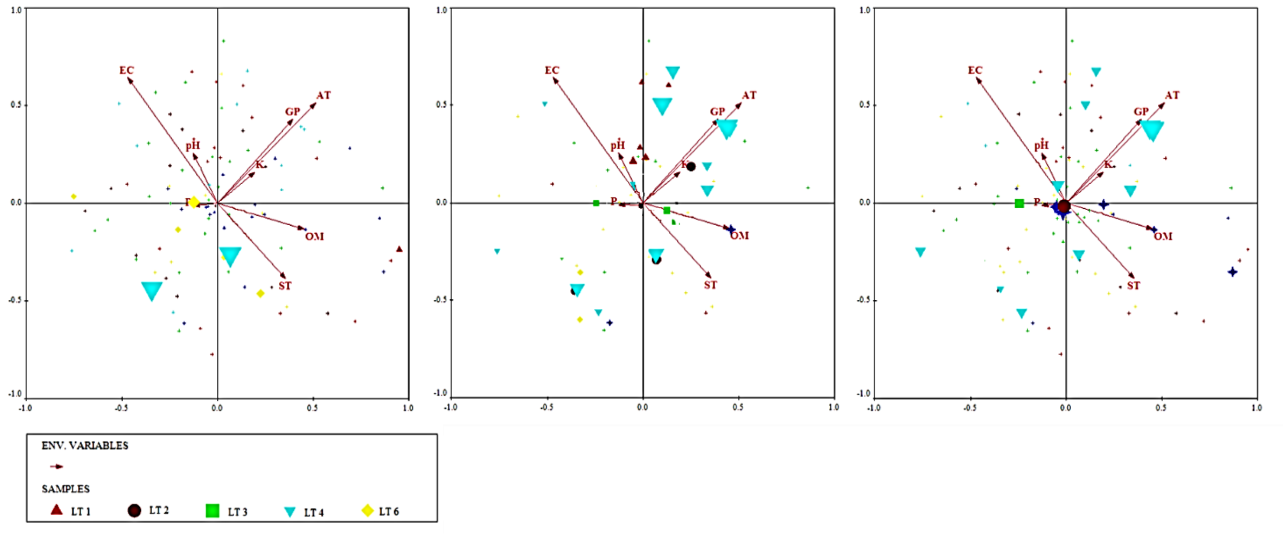

Fig. 6. CCA data attribute plot of indicator species of Landscape type 4.

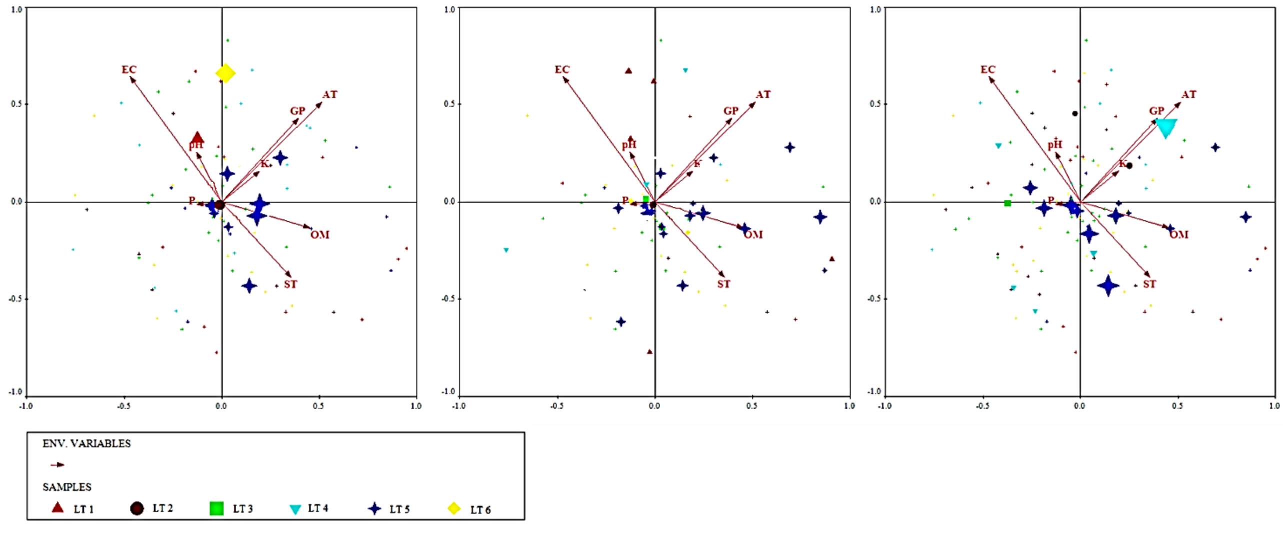

Fig. 7. CCA data attribute plot of indicator species of Landscape type 5.

Table 1. Indicator species of Landscape type and their significance value.

S. No	Indicator species	Variables	IV	P* Values	TIVI
Landscape type 1	*Phoenix dactylifera*	OM	25.5	0.049	62.86
	Lantana camara	EC	46	0.041	334.77
	Bacopa monieri	ST	32.3	0.039	55.95
Landscape type 2	*Acacia modesta*	GP	30.6	0.028	56.81
	Thuja orientalus	Anthropogenic activities	37.7	0.028	55.73
	Erigeron Canadensis	Anthropogenic activities	38.7	0.018	49.69
Landscape type 3	*Dalbergia sissoo*	EC	47.2	0.027	248.96
	Ricinus communis	K	29.6	0.019	73.37
	Parthenium hysterophorus	Anthropogenic activities	49.2	0.044	151.64
Landscape type 4	*Eucalyptus camaldulensis*	Anthropogenic activity	24.3	0.006	111.77
	Dodonaea viscosa	ST	31.8	0.004	205.35
	Diacanthium annulatum	EC	44.7	0.032	49.34
Landscape type 5	*Zizyphus mauritiana*	K	50.6	0.019	60.44
	Carrisa opaca	EC	43.4	0.044	197.13
		ST	32.1	0.004	
	Cyperus niveus	OM	45.2	0.034	30.31
Landscape type 6	*Broussonetia papyrifera*	Anthropogenic activity	23.6	0.019	78.60
	Agave Americana	Anthropogenic activity	31.7	0.012	64.29
		K	50.9	0.019	
	Malvastrum coromandelianum	Anthropogenic activity	40.1	0.006	58.91

IV= Indicator value, OM= Organic Matter, EC= Electric conductivity, ST= Soil Texture, GP= Grazing Pressure, K= Potassium

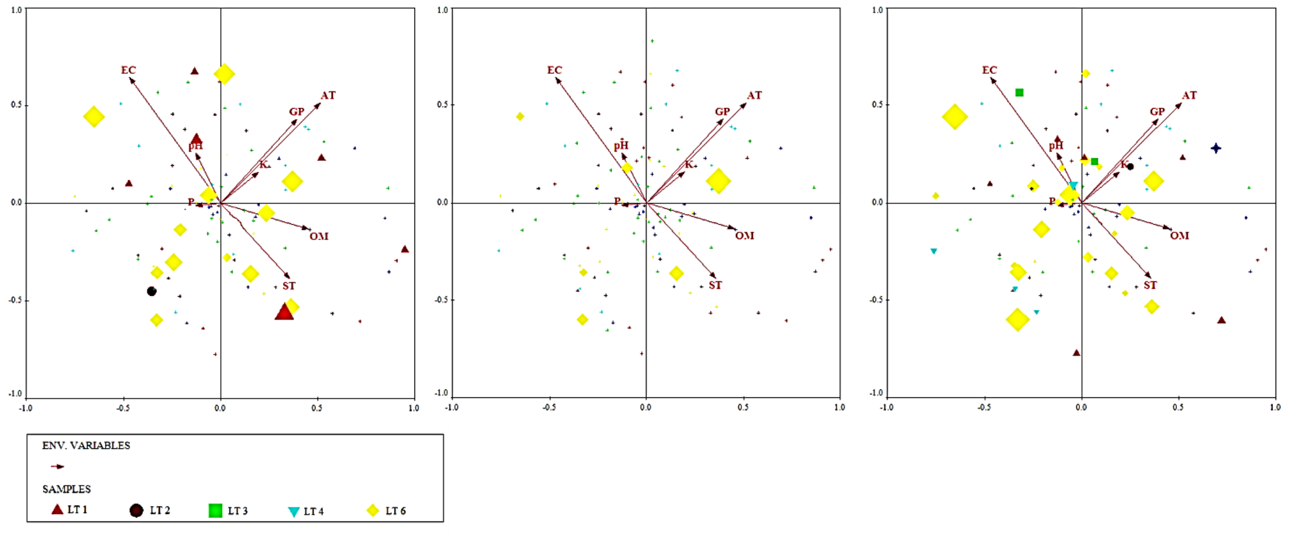

Fig. 8. CCA data attribute plot of indicator species of Landscape type 6.

6) Landscape type 6: *Broussonetia papyrifera - Agave americana - Malvastrum coromandelianum habitat*: This Landscape type was established based on 22 quadrats/stations. The uppermost indicator species of this landscape type were *Broussonetia papyrifera, Agave americana* and *Malvastrum coromandelianum* (Fig. 8). These were the indicators of low potassium concentration in the region (Table 1). *Pongamia pinnata* and *Citharexylum spinosum* dominated the trees layer whereas rare species were *Cupressus sempervirens*, *Celtis eriocarpa*, *Sterculia diversifolia* and *Pterospermum acerifolium*. The shrub layer was dominated by *Adhatoda vasica*, *Lagerstroemia indica* and *Duranta repens* while rare shrubby species were *Periploca aphylla*, *Otostegia limbata*, *Myrsine africana*, *Gymnosporia royleana* and *Buxus papillosa*. *Cynodon dactylon*, *Brachiaria reptans*, *Oxalis corniculata* and *Cannabis sativa* were dominated the herbaceous layer whereas rare herbs were *Rubia cordifolia*, *Polygala abyssinica*, *Persicaria glabra*, *Dysphania ambrosioides* and *Melilotus alba*. This Landscape type was a combination formed by ornamental and dry area plants. This landscape mainly developed on the soil with texture loam, clay loam, sandy clay loam with pH ranging from 6.5 to 7.3. The EC of this landscape ranged from 0.423 to 1.654 ds/m, organic matter deviate from 0.56 to 0.73%, Phosphorus (P)4 to 8 ppm, Potash 71 to 114 ppm and nitrogen level from 0.021–0.002%.

Discussion

The richness of flora is reflected by its particular diversity and floristic composition and such information is necessary for ecological and conservation studies. It is of prime importance to do analyses and critical sampling to understand the crucial influencing factors and vegetation of any geographical region. This study explored 187 plant species, among which 62 plant species were of tree habit, 23 shrub and 102 of herbs. A total of 57 families were reported, out of which 2 were Pteridophytes, 3 were gymnosperm and the remaining 52 were angiosperms (3 monocots and 49 dicots). The dominant family was Poaceae followed by Leguminosae, Lamiaceae, Moraceae, Apocynaceae, Bignoniaceae, Euphorbiaceae, Malvaceae, Verbenaceae and Amaranthaceae. Stewart *et al*., (1972) reported Poaceae as a dominant family. The predominance of Poaceae in these regions due to the physiognomic and climatic conditions i.e. low precipitation and edaphic factors. Microphylls were the dominant leaf form, followed by Mesophylls, Nanophylls and Laptophylls. Badshah *et al.* (2013) also reported microphylls as dominant leaf spectra confirmed the dominancy of microphylls. Dry habitat and adverse conditions mostly prefer species with small leaves i.e. microphylls. The present research also showed that smaller leaves were characteristics of the disturbed habitat and adverse climatic conditions. Microphyll leaf size is the typical grassland and steppes character, whereas nanophylls and leptophylls signify hot deserts (Khan *et al*., 2018; Zeb *et al*., 2020). Wet and warmer regions of the world have plant species that possess larger leaves, whereas dry and cold climates areas have smaller leaves.

Raunkiaer life-form classification was used to classify all the reported plant species into a different life form. The dominating life form was Therophytes and Phanerophytes in the region. Therophytes' dominancy was favored by harsh climatic conditions as investigated by (Batalha & Martins, 2002; Malik *et al*., 2007; Khan *et al*., 2018). PCORD version 5 was used to classify the plant species based on similar floristic composition. Cluster Analysis classified all stations into 6 Landscape types. Indicator Species Analysis further identified the characteristic/indicator species of each sort of habitat. Similarly, Iqbal *et al*., 2018 reported five significant plant associations from District Malakand, Pakistan, using similar techniques. Furthermore, (Anwar *et al*., 2019; Hussain *et al*., 2019; Rahman *et al*., 2020) also used multivariate statistical techniques for the classification of vegetation. Determination of community types and environmental gradients by using Indicator species analysis in vegetation ecology is an emerging technique both in applied and theoretical ecology. The use of ecological indications or multispecies environmental indications instead of the repetitive or single indicator has enormously contributed to the bioindication system and its reliability (Butler *et al*., 2012). Each community or landscape has its characteristic species confirmed through ISA (Indicator species analysis), constancy classes, fidelity level, environmental variables and soil gradients. The same procedure for community composition was also followed by (Pharswan & Mehta, 2010; Khan *et al*., 2011; Khan *et al*., 2013). In current study, indicator species analyses showed that Phosphorous, Nitrogen, Sodium, pH and EC were the strongest and significant edaphic factors ($p \leq 0.05$) for the composition of plant communities and determination of indicator species. (Khan *et al*., 2016) used the same method with unique results from Thandiani Sub-Forest Division of the Western Himalayas.

Indicator Species Analysis (ISA) correlates characteristics species with environmental variables (Anthropogenic activities and grazing pressure) and edaphic factors (Organic matters, electric conductivity, soil texture and Potassium amount). From this analysis, we found that high electric conductivity, low Potassium amount, low organic matters and clay loam soil condition show a strong correlation with indicator species of various Landscapes type. Such a methodology for associations' establishment was also followed by (Ahmed *et al*., 2006; Khan *et al*., 2012; Shaheen & Shinwari, 2012). Anthropogenic activities, grazing pressure, organic matter, soil texture, calcium carbonate, electrical conductivity (EC), nitrogen and pH are the chemical and physical gradients with significant influence on plant species occurrence and their distribution in communities. Multivariate techniques were used by Ahmad *et al*. (2021) to evaluate the complicated bioindicator plants relationship with pollution and their physiological strategies adaptations. (Jabeen & Ahmad, 2009; Haq *et al*., 2020; Zeb *et al*., 2021) used CCA to evaluate the relationship between soil and vegetation. Fuelwood chopping and construction activities are considered anthropogenic disturbances, impacting vegetation structures and declining vegetation. The most vulnerable plant species for wood consumption are *Dodonaea viscosa*, *Carissa opaca*, *justacia adhatoda* and *cassia fistula*. Vegetation diversity and structure are also affected by grazing pressure (Rooney & Waller, 1998). We have also collected extensive data related to functional traits of the Margalla vegetation and is coming in another research paper. It will depict the overall picture of the vegetation in a holistic manner.

Conclusion

It is concluded that the physiochemical properties i.e., nitrogen, potassium, calcium, electrical conductivity, pH, soil texture and anthropogenic activities have a significant effect on distribution pattern, composition, diversity and formation of different landscape types in the Margalla Hills. Future work can be carried out to address the durable outcomes of plant biodiversity loss for the biological ecosystem's sustainability.

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