# SPECIES DIVERSITY AND VEGETATION STRUCTURE FROM DIFFERENT CLIMATIC ZONES OF TEHSIL HARIGHEL, BAGH, AZAD KASMIR, PAKISTAN ANALYSED THROUGH MULTIVARIATE TECHNIQUES

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**Abstract.** The phytosociological survey of western Himalayan subtropical and moist temperate forests of Tehsil Harighel, District Bagh Azad Jammu and Kashmir, Pakistan was carried out during 2015-2017. Sampling was done by using random stratified sampling technique at 12 different sites. Based on importance value twelve plant communities were recognized. They were merged into three plant associations using cluster analysis and Detrended correspondence analysis viz. *Olea -Dodonea – Micromeria* association, *Pinus- Oxalis-Dactylis* association and *Pinus-Diospyros -Myrsine* association. The average number of species per site varied between 17-48, Species richness 3.00 to7.01; Shannon Diversity 2.49 to 3.82; Evenness 0.46 to 0.72 and Equitability 0.73 to 0.91. Canonical Correspondence Analysis (CCA) revealed that altitude and edaphic characteristics like potassium, organic matter, saturation, electrical conductivity and pH play a significant role in controlling the distribution pattern of plant species. Low value of species diversity and associated components clearly reflect that forest structure is deteriorated in the investigated area with poor regeneration potential. Therefore, immediate conservation measures by integrating local populations' perceptions are urgently recommended.
**Keywords:** *environmental gradient, cluster analysis, richness, DCA, CCA*

## Introduction

Vegetation structure, species composition, diversity and richness pattern, maturity value are the important ecological characteristics that are highly correlated with anthropogenic and environmental variables (Gairola et al., 2008; Shaheen et al., 2011a; Ahmad et al., 2013; Amjad et al., 2014a, b; Ilyas et al., 2015). Vegetation is the distinct physiognomic unit whose structure can be clearly differentiated from other such unit (Hussain and Illahi, 1991). Vegetation, soil and climate are interrelated with each other. The variation in any one of these components may bring change in the associated component (Kent, 2012; Amjad et al., 2014b; Ilyas et al., 2015). Geographical or topographical factors like altitude and aspect play critical role in structuring vegetation (Ellenberg, 1996; Gallardo-Cruz et al., 2009; Scherrer and Korner, 2010; Shaheen et al., 2011b). Vegetation is the chief component of environment in majority of habitat which


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facilitates the ecosystem services and biodiversity (Gardner et al., 2009). Therefore assessment of vegetation structure is the main indicator in conservation and ecosystem management.

Species diversity is a function of the number of species present in a given area and reflects the productivity and health of ecosystem (Ruiz et al., 2008). The most easily interpretable indicator of diversity is species richness which is controlled by a complex of environmental variables (Whittaker, 1977; Shrestha and Jha, 2009) mainly altitude, aspect and moisture (Vetaas, 2000; Schuster and Diekmann, 2005) The precise diversity measurement is helpful in understanding the various phenomena involved in organization and development of plant communities (Shoukat et al., 1978; Malik and Malik, 2012). The anthropogenic pressure in the form of deforestation, overgrazing and fuel wood extraction can be clearly reflected from low species diversity and richness in the area. Thus vegetation structure information along with species biodiversity assessment is a prerequisite for biodiversity conservation and ecosystem management (Willoughby and Alexander, 2000, 2005).

The computer-based multivariate statistical techniques helps ecologists in structuring large data sets and analyzing impact of environmental factors on distribution pattern of plant species (Bergmeier, 2002; Anderson et al., 2006). Such techniques reduce the complexity of data by classifying vegetation and relating the results to abiotc (environmental) components (Dufrene and Legendre, 1997; McCune and Mefford, 1999; Ter Braak and Prentice, 1988). Various multivariate techniques such as Two way Indicator species analysis, Cluster analysis, Canonical correspondence analysis and Detrended correspondence analysis have been extensively employed by ecologists recognize the environmental gradient among vegetation structure and species diversity in mountainous ecosystems (Daubenmire, 1968; Vetaas and Grytnes, 2002; Tavili and Jafari, 2009).

Azad Jammu & Kashmir, Pakistan harboured diverse climate, soil type and rich diversity. Various studies have been conducted previously to analyze vegetation in different part of Azad Jammu & Kashmir (Siddiqui et al., 2010; Shaheen et al., 2011a; Malik and Malik, 2012; Amjad et al., 2014a,b; Bokhari et al., 2016; Amjad et al., 2017). However many potentially diverse remote areas like Harigal were not still explored by the ecologist particularly using advanced phytosociological techniques. Moreover previous studies are restricted to floristic inventory and quantitative attributes and lack novelty in term of multivariate analysis. Therefore present study was designed to analyze the variation among species diversity and vegetation structure along the environmental gradient using multivariate approach. The findings of current research work will be helpful for designing effective conservation strategies for sustainable management of plant resources of area particular for minimizing anthropogenic pressure.

## Materials and methods

### *Study area*

Tehsil Harighel of District Bagh, Azad Jammu & Kashmir, Pakistan is located in western Himalayan foot hills of Pir-Panjal range between latitude 33°54'-34°08' N and longitude 73°01'-73°38' E longitude. The altitude of area varies between 980 m to 2052 m. Total area of District Bagh is 1368 $km^2$ with 54.78% under forest cover. Population is 0.434 million (Anonymous 2007). The climate of area varies from


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subtropical humid to temperate type at various elevations with mean annual precipitation of 1500 mm. The average annual temperature is 21 °C with maximum up to 40 °C during July and minimum up to 2 °C during January (Anonymous, 2009; Shaheen et al., 2011a).

### *Collection and identification of plant specimen*

Three plant specimens of each species were collected. The specimens were carefully dried and mounted on herbarium sheet. Different floras and monograph of various areas of Pakistan were used for Identification of specimens. The identified specimens were confirmed at AJ&K Medicinal and Aromatic Plant Herbarium PARC, Pakistan. International Plant Name Index (IPNI) was used to obtain correct botanical name. The identified specimens were deposited in Herbarium of Women University of Azad Jammu & Kashmir Bagh.

### *Field sampling*

Field surveys were carried out during 2014-2016 following specific locality procedure. Twelve sites were selected based on altitude, aspect and physiognomy (*Fig. 1*). The altitude and geographical coordinates of each site was determined by using GPS and aspect by using Suunto Tandem survey master compass. Detailed stratified sampling was done using quadrat method. The quadrat size was 1 ×1 $m^2$, 5 ×5 $m^2$and 10 × 10 $m^2$for herbs, shrubs and trees respectively. Composition and abundance data of plant species were recorded from each quadrat on prepared Excel data sheets.

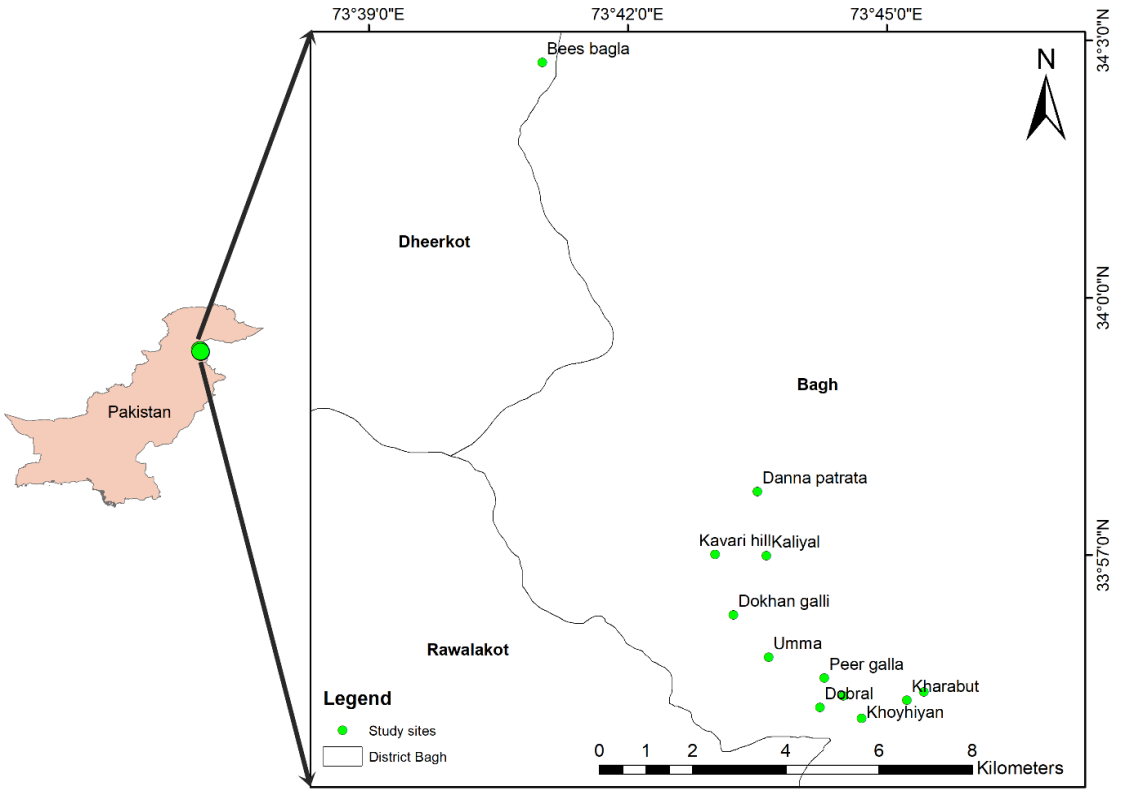


***Figure 1.*** *Map showing location of different study sites*


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Three soil samples were collected from each site at depth of 15 cm and mixed to make composite. Different physico-chemical properties of soil like texture, pH, organic matter, electrical conductivity, saturation, % of phosphorous, potassium and calcium carbonate were determined in Pakistan Soil and Water Testing Laboratory Rawalpindi using standard methods (Jackson, 1962; Hussain, 1989).

***Data storage and analysis***

The importance value of each plant species was recorded following Curtis and McIntosh (1950) by using *Equation 1:*

$$IVI = R.D + R.F + R.C. \quad \text{(Eq.1)}$$

where IVI = importance value index, R.D = relative density, R.F = relative frequency, and R.C. = relative cover.

Species diversity was calculated by following Shannon (1949) by using *Equation 2:*

$$H = \sum\left(\frac{n}{N} \times \frac{ln\ (n)}{ln\ (N)}\right) \quad \text{(Eq.2)}$$

where H = species diversity, n = number of individual of its species, N = total number of individual of all species.

Species richness was calculated by following Margalef (1958) using *Equation 3:*

$$R = \frac{S-1}{ln\ (N)} \quad \text{(Eq.3)}$$

where R = species richness, N = total number of individual of all species.

Equitability was calculated by following Sheldon (1969) using *Equation 4:*

$$E = \frac{H}{\ln\ (S)} \quad \text{(Eq.4)}$$

where H = Diversity, S = total number of species.

Evenness was calculated by following Gibson's evenness index using *Equation 5:*

$$G = \frac{eH}{S} \quad \text{(Eq.5)}$$

where, H = Diversity, S = total number of species.

Species maturity was calculated by following Pichi-Sermollis (1948) using *Equation 6:*

$$M = \frac{F}{S} \quad \text{(Eq.6)}$$

where, M= Species maturity, F = total frequency, S = total species number.

Species composition and abundance data of 158 species and 7 environmental variables from 390 quadrats at twelve different sampling sites (390 quadrats) were processed in MS Excel in accordance with the PCORD V.5 and CANACOO V.5 requirements. The grouping of plant species was carried out by using cluster analysis in PC ORD software (McCune and Grace, 2002; McCune and Mefford, 2005). Wards


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method was used as linkage method to group the same stands. These associations were documented at three level of division on the bases of dendrogram. The vegetation and environmental data was further subjected to ordination analysis using CANACOO version 5.00 (TerBraak and Smilauer, 2002). DCA and CCA analysis was carried out to verify the faithfulness of grouping/association, check the ecological gradient of plant association and to find the vegetation environmental relation. The explanatory power (strength) of different environmental factors was checked by Monte Carlo Permutation test (reduced model, 4999 permutations).

## Results

Based on cluster analysis and DCA, 158 plant species and 12 sites were grouped into three associations (*Fig. 2*) which are as follows:

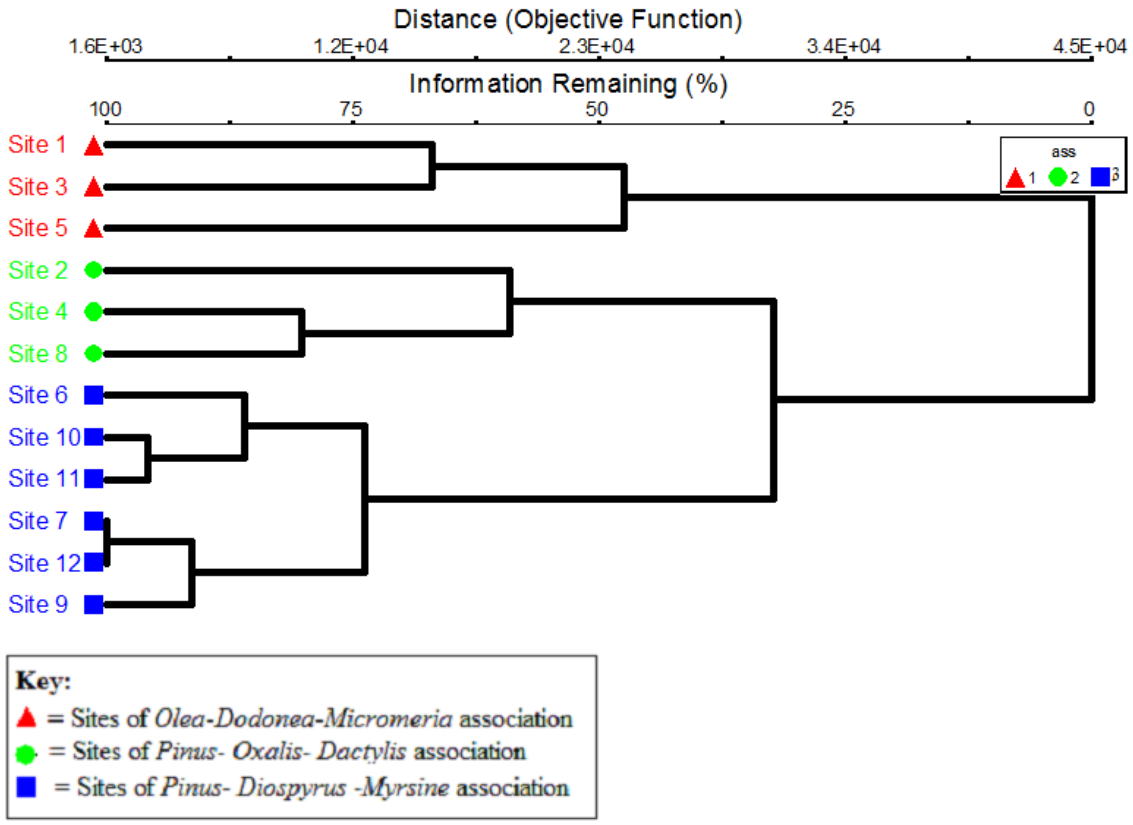


***Figure 2.*** *Cluster analysis dendrogram representing three plant associations*

### *Olea-Dodonea-Micromeria (A) association*

This association harboured at an altitudinal range of 980-1165 m. The association comprised of three communities having 51 species which include 3 trees, 15 shrubs and 33 herbs. The dominant species were *Olea ferruginea* (I.V = 60.02), *Dodoneae viscosa* (IV = 27.21) and *Micromeria biflora* (I9.92). Whereas *Berberis lycium, Maytenus nemorosa* and *Ficus palmata* were associated plant species (*Table 1*). Soil was loamy with average pH of 7.36. Soil saturation was 40%; electrical conductivity 0.83 µs/cm; organic matter 0.73%; phosphorus 3.66 $mgKg^{-1}$ and potassium 106.66 $mgKg^{-1}$.


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### *Pinus-Oxalis-Dactylis (B) association*

This association lies in between 1079 and 1658 m and consisted of 3 plant communities having 79 Plant species which include 8 trees, 15 shrubs and 56 herbs. *Pinus roxburghii* (I. V = 33.65), *Oxalis spiralis* (I. V = 12.64) and *Dactylis glomerata* (I. V = 11.81) were dominant. Whereas *Myrsine Africana* and *Indigofera linifolia* were associated plant species (*Table 1*). Soil texture was loamy with average pH 7.17. Soil saturation 39.66%; electrical conductivity 0.70 µs/cm; organic matter 0.76%; phosphorus 4.4 mg $kg^{-1}$ and potassium 120 mg $kg^{-1}$.

### *Pinus-Diospyrus-Myrsine (C) association*

This association was recorded at an altitude of 1450-20520 m having 6 Plant communities having 110 species. *Pinus wallichiana* (I. V = 40.13), *Diospyrus lotus* (I. V = 11.84) and *Myrsine Africana* (I. V = 9.78) were dominant. *Quercus dilitata*, *Berberis lycium*, *Sarcococca saligna* and *Vibernum grandiflorum* were the associated plant species (*Table 1*). Soil was loamy with average pH of 7.23. Soil saturation was 40.05%; electrical conductivity 0.64 µs/cm; organic matter 0.81; phosphorus 5.33 mgKg $^{-1}$ and potassium 116.66 mg $kg^{-1}$.

***Table 1.*** *Mean relative importance value of species in three associations recorded by normal cluster analysis during monsoon 2016 from Tehsil Harighel*

| Species name | Abbrev. | Association A | Association B | Association C |
|---|---|---|---|---|
| *Olea ferruginea* Royle. | Ole fer | 60.02 | 9.01 | 3.55 |
| *Pinus roxburghii* Sarg. | Pin rox | 9.71 | 33.65 | 2.32 |
| *Acacia nilotica* (L.) Wild. ex Delile | Aca nil | 2.47 | 0 | 1.47 |
| *Pyrus pashia* Buch.-Ham. ex D. Don | Pyr pas | 0 | 6.21 | 4.97 |
| *Diospyros lotus* L. | Dio lot | 0 | 5.16 | 11.84 |
| *Pinus wallichiana* L. | Pin wal | 0 | 8.22 | 40.13 |
| *Ailanthus altissima (*Mill.) Swingle | Ail alt | 0 | 4.09 | 1.04 |
| *Quercus dilatata* Lindl. | Que dil | 0 | 0 | 9.52 |
| *Dalbergia sissoo* Roxb. ex DC | Dal sis | 0 | 0 | 0.39 |
| *Broussonetia papyrifera* (L.) L Her. Ex Vent. | Bro pap | 0 | 0 | 0.88 |
| *Juglans regia* L. | Jug reg | 0 | 0 | 1.56 |
| *Aesculus indica* (Wall. ex Cambess.) Hook. | Aes ind | 0 | 0 | 1.00 |
| *Mimosa pudica* L. | Mim pud | 0 | 0 | 0.64 |
| *Quercus incana* Roxb. | Que ina | 0 | 1.90 | 4.63 |
| *Salix nigra* Marshall | Sal nig | 0 | 2.40 | 0 |
| *Bauhinia variegate* L. | Bau var | 0 | 0 | 1.08 |
| *Dodonaea viscosa* (L.) Jacq. | Dod vis | 27.21 | 0 | 0 |
| *Maytenus nemorosa* Marais | May nem | 10.83 | 0 | 0 |
| *Myrsine africana* L. | Myr afr | 8.55 | 11.09 | 9.78 |
| *Berberis lycium* Royle. | Ber lyc | 11.80 | 5.98 | 9.23 |
| *Cotoneaster racemiflorae* Pojark. | Cot rac | 4.32 | 2.68 | 1.65 |
| *Zanthozylum alatum* Roxb. | Zan ala | 5.12 | 4.07 | 2.43 |


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|---|---|---|---|---|
| *Nerium oleander* L. | Ner ole | 6.46 | 0 | 0.77 |
| *Rubus fruticosus* L. | Rub fru | 0 | 0 | 0.72 |
| *Indigofera linifolia (*L. f.) Retz | Ind lin | 0 | 10.12 | 3.76 |
| *Viburnum grandiflorum* Wall. ex DC. | Vib gra | 0 | 0 | 8.70 |
| *Rosa brunonii* Lindl. | Ros bru | 1.30 | 5.42 | 4.64 |
| *Ricinus communis* L. | Ric com | 0 | 2.03 | 0 |
| *Wikstroemia canescens* Wall. ex Meisn. | Wik can | 1.61 | 6.53 | 5.90 |
| *Debregearsia salcifolia* | Deb sal | 0 | 6.38 | 0.75 |
| *Sarcococca saligna* (D. Don) Müll. Arg. | Sar sal | 0 | 3.20 | 8.18 |
| *Ziziphus mauritiana* Lams. | Ziz mau | 2.69 | 0 | 0 |
| *Adhatoda zeylanica* Medik. | Adh zey | 0 | 0 | 0.81 |
| *Desmodium elegans* Schltdl. | Des ele | 0 | 0 | 0.49 |
| *Petrorhagia saxifraga* (L.) Link | Pet sax | 0 | 0 | 0.40 |
| *Rubus niveus* Wall. ex G. Don | Rub niv | 0 | 0 | 1.14 |
| *Jasminum grandiflorum* L. | Jas gra | 0 | 0 | 1.28 |
| *Ficus palmata* Forssk. | Fic pal | 10.24 | 4.59 | 3.74 |
| *Punica granatum* L | Pun gra | 4.98 | 2.49 | 2.44 |
| *Rubus ellipticus* Sm. | Rub ell | 0 | 8.70 | 1.28 |
| *Elaeagnus umbellate* | Ela umb | 0 | 0 | 2.14 |
| *Oteostagia limbata* (Benth.) Boiss. | Ote lim | 3.83 | 0 | 0 |
| *Rumex hastatus* D. Don | Rum has | 1.10 | 2.61 | 0.97 |
| *Rhus catinus* Scop. | Rhu cat | 1.66 | 2.03 | 1.07 |
| *Machilus odoratissimus* Nees | Mac odo | 0 | 2.52 | 2.41 |
| *Jasminum humile* L. | Jas hum | 0 | 0 | 0.49 |
| *Asplenium adiantum-nigrum* L. | Asp adi | 0 | 2.31 | 0.89 |
| *Lespedeza juncea* (L. f.) Pers. | Les jun | 4.36 | 3.05 | 0 |
| *Senecio amplectens* A. Gray | Sen amp | 0 | 2.33 | 0.47 |
| *Adiantum caudatum* L. | Adi cau | 0 | 1.08 | 2.90 |
| *Clinopodium vulgare* L. | Cli vul | 0 | 0.90 | 0 |
| *Scutellaria ovata* Hill | Scu ova | 5.83 | 0.96 | 0 |
| *Eulaliopsis binata* Retz. | Eul bin | 5.48 | 1.18 | 0 |
| *Adiantum incisum* Forssk. | Adi inc | 0 | 0.30 | 0 |
| *Oenothera rosea* L Her. ex Aiton | Oen ros | 0 | 0.47 | 6.70 |
| *Thalictrum Spp.* | Tal spp | 0 | 1.06 | 0.73 |
| *Androsace rotundifolia* Hardw. | And rot | 1.21 | 0.51 | 0.78 |
| *Micromeria biflora (*Buch.-Ham. ex D. Don) Benth. | Mic bif | 19.92 | 7.48 | 7.11 |
| *Poa pratensis L* | Poa pra | 0 | 0 | 1.26 |
| *Ajuga parviflora* Benth. | Aju par | 1.38 | 0 | 1.64 |
| *Setaria pumila* (Poir.) Roem. & Schult. | Set pum | 5.47 | 0 | 0 |
| *Lepidium ruderale* L**.** | Lep rud | 0 | 5.57 | 0 |
| *Oxalis spiralis* Ruiz & Pav. ex G. Don | Oxa spi | 0 | 12.64 | 1.77 |
| *Fragaria visca* L. | Fra vis | 0 | 0.62 | 4.60 |
| *Sonchus arvensis* L. | Son arv | 0 | 0.94 | 1.29 |


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|---|---|---|---|---|
| *Clinopodium umbrosum* (M. Bieb.) K. Koch | Cli umb | 0 | 2.05 | 0 |
| *Oxalis corniculata* L. | Oxa cor | 0 | 7.43 | 0 |
| *Pteris cretica* L. | Pte cre | 0 | 4.83 | 2.80 |
| *Origanum vulgare L.* | Ori vul | 0 | 0 | 0.23 |
| *Dryopteris filix*-mas (L.) Schott | Dry fil | 7.03 | 2.78 | 0 |
| *Dactylis glomerata* L. | Dac glo | 0 | 11.81 | 0.54 |
| *Bidens biternata* (Lour.) Merr. & Sherff | Bid bit | 4.16 | 0 | 0 |
| *Themeda anathera* (Nees ex Steud.) Hack | The ana | 6.78 | 8.47 | 0 |
| *Conyza canadensis (*L.) Cronquist | Con can | 1.49 | 0 | 1.07 |
| *Ipomoea purpurea* (L.) Lam. | Ipo pur | 4.21 | 0 | 0.73 |
| *Taraxacum officinale* L. | Tar ofi | 2.73 | 0.28 | 2.40 |
| *Veronica laxa* (Benth.) | Ver lax | 2.89 | 4.85 | 0.87 |
| *Carpesium abrotanoides* L. | Car abr | 2.25 | 0 | 0 |
| *Crotalaria juncea L.* | Cro jun | 4.95 | 0 | 0 |
| *Agrostis stolonifera L.* | Agr sto | 3.40 | 0 | 0.58 |
| *Gerbera gossypina (*Royle) Beauverd | Ger gos | 0 | 4.78 | 1.81 |
| *Verbascum thapsun* L. | Ver tha | 0.07 | 0.33 | 0 |
| *Geranium ocellatum* Cambess | Ger oce | 0 | 0.62 | 0 |
| *Cynoglosum lanceolatum* Forssk | Cyn lan | 0 | 0.04 | 0.45 |
| *Galium aparine* L. | Gal apa | 0 | 2.25 | 6.19 |
| *Vicia sativa Guss.* | Vic sat | 0 | 0.74 | 1.69 |
| *Cynodon dactylon (*L.) Pers. | Cyn dac | 0 | 2.85 | 2.94 |
| *Pteris umbrosa* R. Br. | Pte umb | 0.73 | 0 | 0 |
| *Cichorium intybus* L. | Cic int | 0 | 0.97 | 0 |
| *Prunella vulgaris* L. | Pru vul | 0 | 0.99 | 1.95 |
| *Viola canescens* Wall. | Vio can | 0 | 1.44 | 0 |
| *Euphorbia helioscopia* L. | Eup hel | 0 | 6.98 | 0 |
| *Arundo donax* L. | Aru don | 0 | 0.87 | 0 |
| *Onopordum acanthium* L. | Ono aca | 0 | 1.65 | 0 |
| *Mentha arvensis* L. | Men arv | 0 | 2.54 | 1.23 |
| *Mentha longifolia* L. | Men lon | 0 | 1.49 | 1.69 |
| *Epipactis helleborine* (L.) Crantz | Epi hel | 0 | 3.57 | 0 |
| *Cyprus niveus* | Cyp niv | 0 | 1.53 | 1.46 |
| *Silybum marianum (*L.) Gaertn. | Sil mar | 0.40 | 0 | 0.43 |
| *Euphorbia hirta* | Eup hir | 0.07 | 0 | 1.77 |
| *Aegopodium podagraria L.* | Aeg pod | 12.08 | 0 | 0 |
| *Valerianella szovitsiana* Fisch. & C.A. Mey. | Val szo | 3.38 | 0 | 0 |
| *Linum spp.* | Lin spp | 0 | 0 | 1.69 |
| *Trichodesma indicum* (L.) Lehm | Tri ind | 6.45 | 0 | 0 |
| *Astragalus leucocephalus* Graham ex Benth. | Ast leu | 1.64 | 0 | 0 |
| *Salvia lanata* Roxb. | Sal lan | 2.21 | 0 | 0 |
| *Trifolium repens* L. | Tri rep | 0 | 0 | 5.16 |
| *Polygala abyssinica* R. Br. ex Fresen | Pol aby | 3.88 | 0 | 0 |


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|---|---|---|---|---|
| *Spirace canescans* | Spi can | 2.56 | 0 | 0 |
| *Plantago major* L. | Pla maj | 0 | 0 | 4.77 |
| *Lactuca floridana* (*L.*) Gaertn. | Lac flo | 0 | 0 | 0.53 |
| *Adiantum capillus-veneris* L. | Adi cap | 0 | 0 | 1.98 |
| *Ranunculus arvensis* L | Ran arv | 0 | 2.11 | 2.13 |
| *Ranunculus sceleratus* L. | Ran sce | 0 | 0 | 4.65 |
| *Hedera nepalensis K*. Koch | Hed nep | 3.00 | 0 | 2.98 |
| *Pennisetum orientale* Rich. | Pen ori | 12.48 | 1.17 | 1.01 |
| *Cannabis sativa* L. | Can sat | 0 | 4.32 | 0 |
| *Plantago lanceolata* L. | Pla lan | 0 | 3.44 | 2.72 |
| *Plectranthus spp* | Ple spp | 0 | 1.58 | 0 |
| *Solanum nigrum* L. | Sol nig | 0 | 2.43 | 0 |
| *Lathyrus aphaca* L. | Lat aph | 0 | 1.25 | 0 |
| *Juncus articulates* | Jun art | 0 | 0 | 1.03 |
| *Cirsium vulgare (*Savi) Ten | Cir vul | 0 | 0 | 0.41 |
| *Dicliptera bupleuroides* Nees | Dic bup | 0 | 0 | 1.46 |
| *Phlomis bracteosa Royle ex Benth.* | Phl bra | 0 | 0 | 0.63 |
| *Polygonatum geminiflorum Decne.* | Pol gem | 0 | 0 | 1.77 |
| *Dryopterious odantoloma* | Dry oda | 0 | 0 | 0.95 |
| *Thymus linearis* Benth. | Thy lin | 0 | 0 | 1.79 |
| *Achillea millefolium* L. | Ach mil | 0 | 0 | 0.94 |
| *Vicia monantha* Retz. | Vic mon | 0 | 0 | 0.76 |
| *Artemisia vulgaris L.* | Art vul | 0 | 0 | 2.09 |
| *Astrogates condolleances* | Ast con | 0 | 0 | 0.56 |
| *Adiantum tenerum* Sw. | Adi ten | 0 | 0 | 0.93 |
| *Anaphalis triplinervis* (Sims) C.B. Clarke | Ana tri | 0 | 0 | 0.33 |
| *Onopordum acanthum* | Ono aca | 0 | 1.65 | 0 |
| *Urtica dioca* L | Urt dio | 0 | 0 | 0.85 |
| *Scutellaria chamaedrifolia* Hedge & Paton | Scu cha | 0 | 0 | 0.10 |
| *Serratula praealta* L. | Ser pra | 0 | 0 | 0.59 |
| *Clematis grata* Wall. | Cle gra | 0 | 0 | 0.64 |
| *Silene conoidea* L. | Sil con | 0 | 0 | 0.36 |
| *Convolvulus arvensis* L. | Con arv | 0 | 0 | 0.67 |
| *Anagalis arvensis* L. | Ana arv | 1.17 | 0 | 0.47 |
| *Barleria cristata* L. | Bar cri | 3.24 | 0 | 0 |
| *Stellaria media (*L.) Cirillo | Ste med | 0 | 0.83 | 0 |
| *Rumex dantatus* L | Rum dan | 2.29 | 0 | 0.23 |
| *Fragaria nubicola* | Fra nub | 0 | 0 | 4.61 |
| *Duchesnia indica* (Andr.) Focke | Dus ind | 0 | 2.86 | 0 |
| *Adiantum venustum* D. Don | Adi ven | 0 | 0 | 0.76 |
| *Hedera helix K.*Koch | Hed hel | 0 | 2.56 | 1.14 |
| *Brachiaria reptans* (L.) C.A. Gardner & C.E. Hubb. | Bra rep | 0 | 0 | 0.09 |
| *Pteris cheltron Andr.* | Pte che | 0 | 0 | 1.15 |


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| | | | | |
|---|---|---|---|---|
| *Vincetoxicum hirundinaria* Medik. | Vin hir | 0 | 0 | 0.69 |
| *Galium asprellum* Michx. | Gal asp | 0 | 4.39 | 2.12 |
| *Galium asperuloides* Edgew. S | Gal aspe | 0 | 0 | 1.56 |
| *Galium elegan* Blocki | Gal ele | 0 | 0.79 | 0 |
| *Clematis barbellate*Edgew. | Cle bar | 0 | 0.90 | 0 |
| *Medicago polymorpha* L. | Med pol | 0 | 0 | 0.72 |

A = Olea-Dodonea-Micromeria association; B = Pinus-Oxalis-Dactylis association; C = Pinus-Diospyrus-Myrsine association

### *Detrended correspondence analysis*

Detrended Correspondence analysis is the indirect gradient analysis which applied here to highlight the ecological gradients controlling the spatial variations among the plant species. Sum of all variance or eigen values was 3.93. The first Eigen value was proven to be quite high (0.57) which reflect strong gradient strength in species distribution patterning along this DCA axis. The DCA diagram explains altitudinal, aspect and environmental gradient. The sites and species of lower altitude, northern aspect and mesic habitat (*Pinus-Diospyros-Myrsine* association) were positioned on right side of diagram whereas site and species of higher altitude southern aspect and xeric habitat (*Olea -Dodonea –Micromeria* association) were positioned on left side of diagram (*Figs. 3* and *4*).

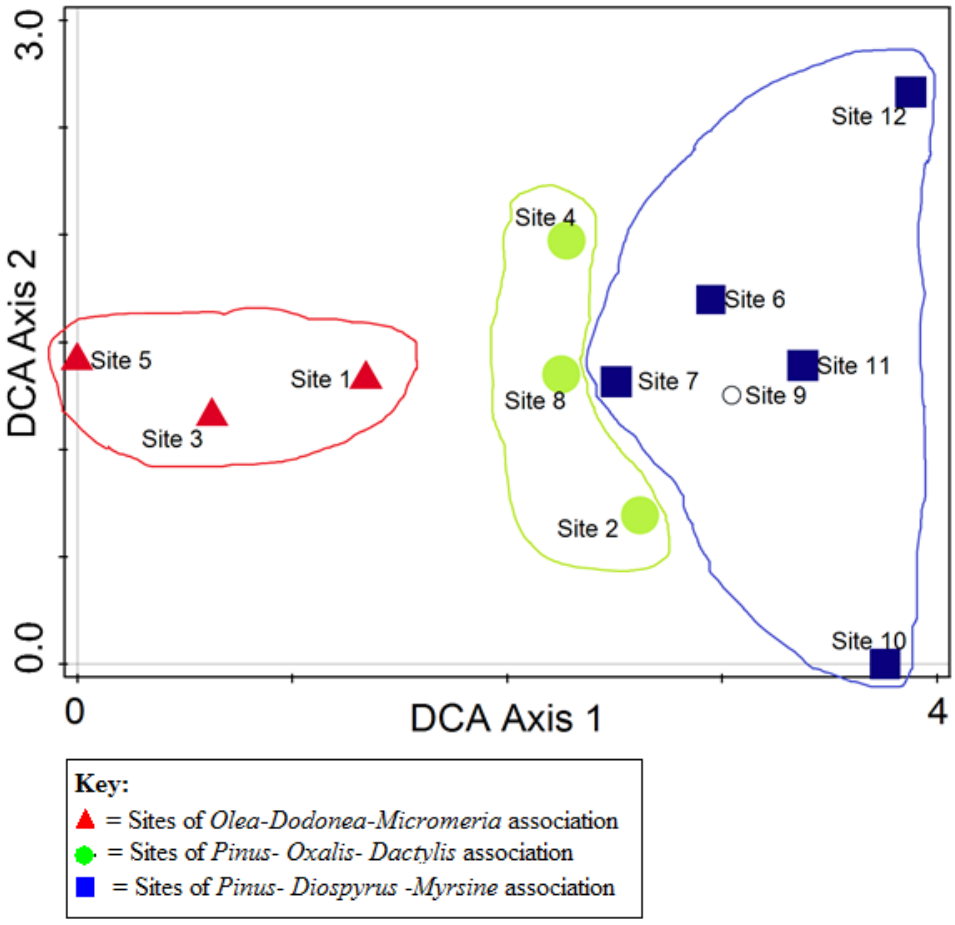


***Figure 3.*** *DCA analysis diagram representing distribution pattern of plant association*


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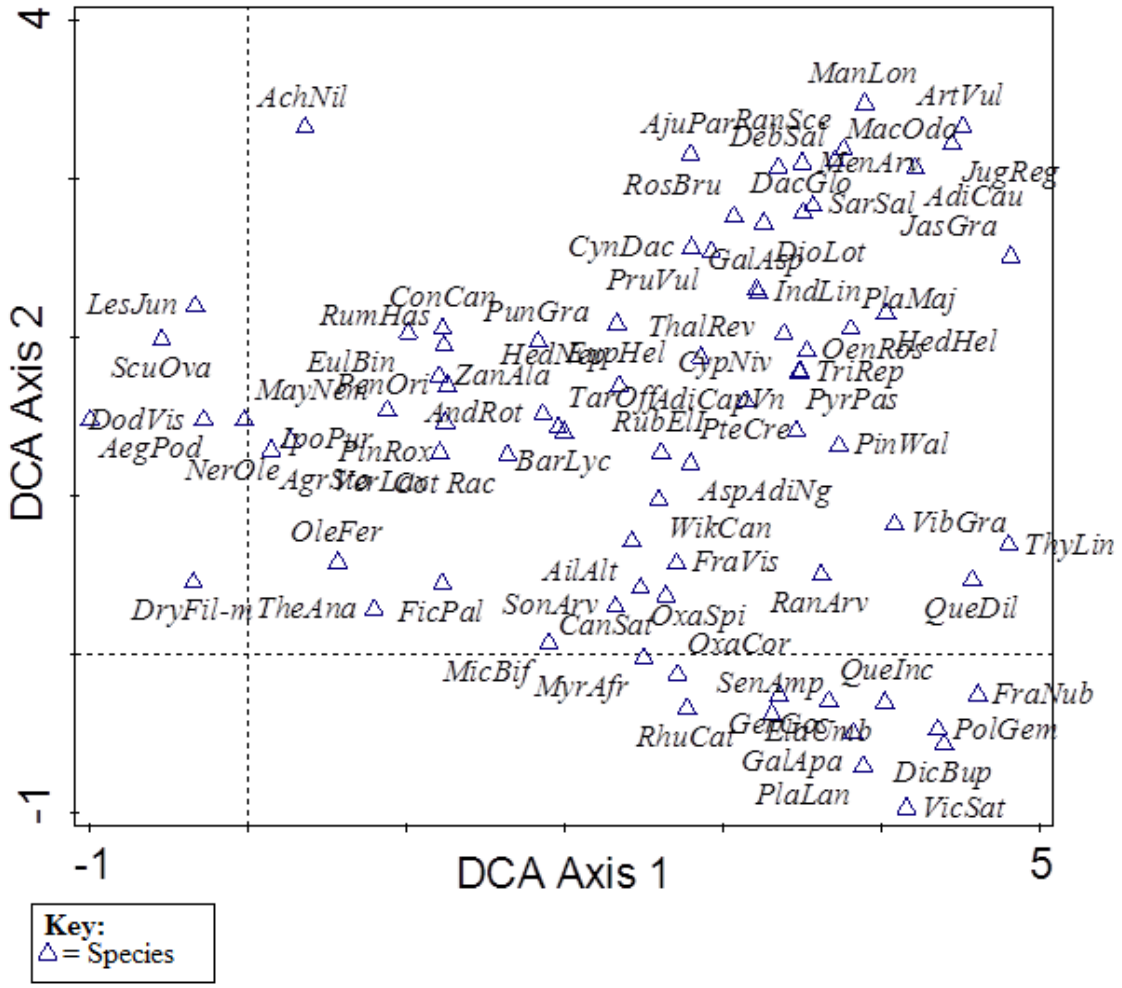


***Figure 4.*** *DCA diagram showing distribution of plant species*

### *Canonical correspondence analysis*

Canonical correspondence analysis (CCA) was carried out here to find the relationship between environmental factors and species distribution pattern in different zones of Tehsil Harighel. The high Eigen value of first axis explains high gradient strength along this axis. Nearly half of variation is explained by first two axes therefore remaining two axis were excluded. CCA revealed Altitude and soil physic-chemical properties particularly potassium content, organic matter, electric conductivity and pH play a significant role in the distribution of plant species while phosphorous and saturation play minor role. The communities harboured at site 1, site 6 and site 7 were under cumulative influence of pH and electric conductivity. The plant community of sites 2 and site 3 has significant correlation with electric conductivity. The plant communities of site 4 were under cumulative influence of electric conductivity and potassium. Whereas plant communities of site 9, site 11 and site 12 were under cumulative influence of altitude, potassium and saturation. Site 4 was outlier and not affected by any environmental variable (*Fig. 5*). Maximum number of species were not affected by any environmental variable as they are located in the center of diagram. E.C play a significant role in grouping of *Pinus roxburghii, Punica granatum, Indigofera*


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*linifolia, Rubus ellipticus, Rumex hastatus*. The pH showed strong correlation with *Olea ferruginea, Dodonea viscosa, Dryopteris filix-mas, Silybum marianum* and *Scutellariaovata*. Organic matter plays a significant role in distribution of *Jasminum grandiflorum, Dicliptera bupleuroides, Fragaria nubicola* and *Thymus linearis*. Saturation, phosphorus and potassium are important in distribution of *Machilus odoratissimus, Rosa brunonii, Cyprus niveus, Urticadioca, Scutellaria chamaedrifolia, Mentha arvensi* and *Mantha longifolia* (*Fig. 6*).

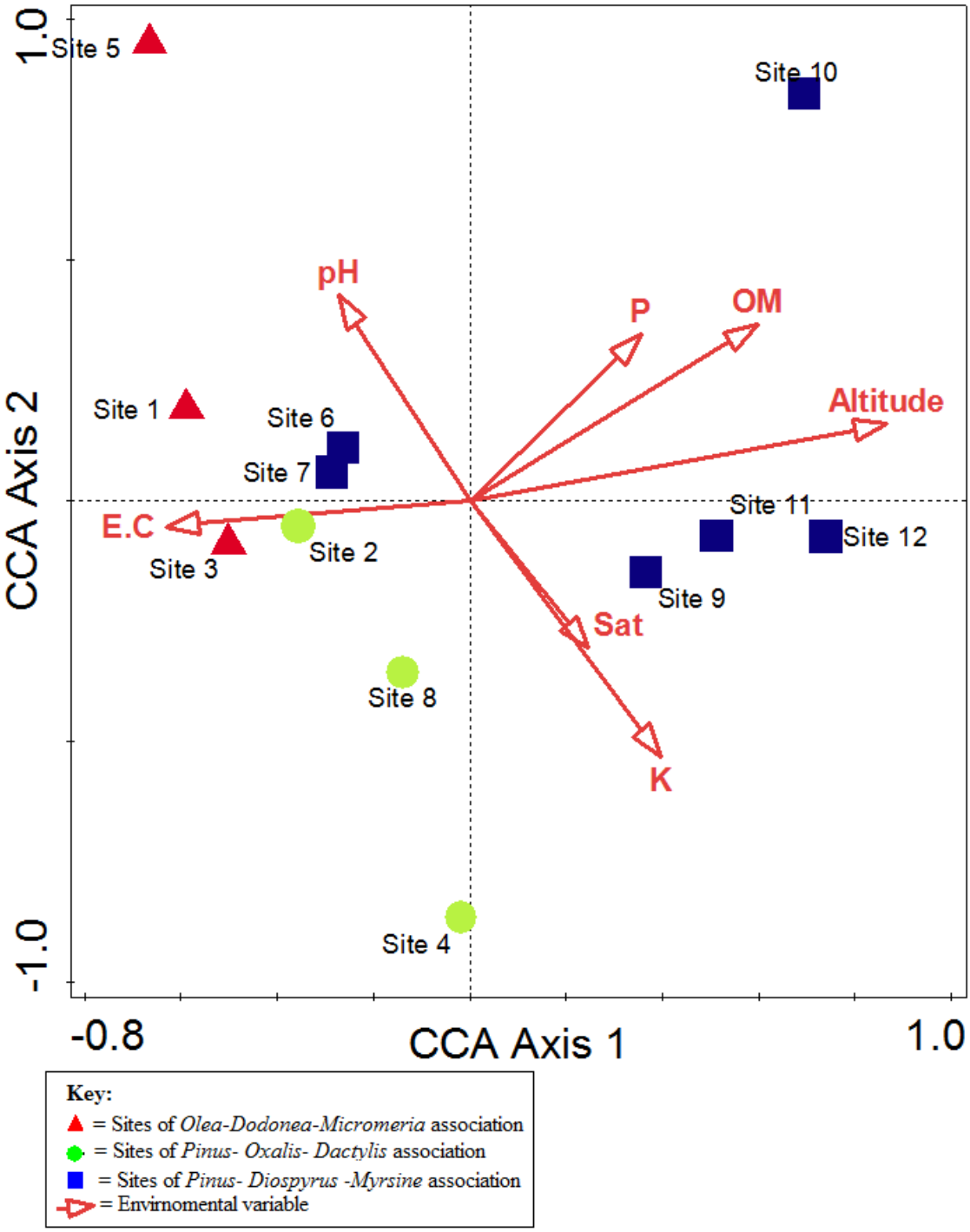


***Figure 5.*** *CCA biplot diagram showing distribution of sites along the environmental variable*


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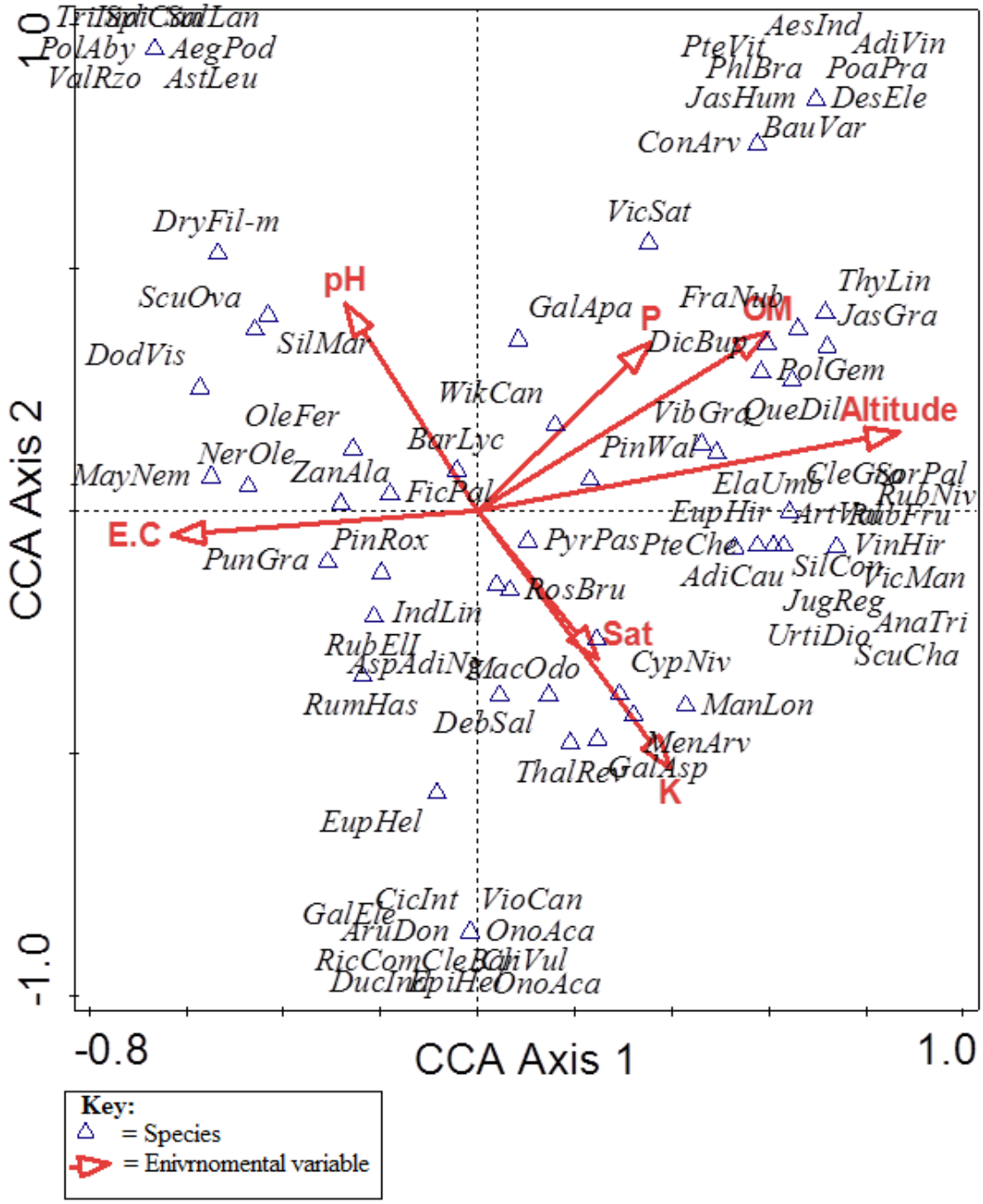


***Figure 6.*** *CCA biplot diagram showing distribution of plant species along the environmental variable*

### *Species diversity and its associated components*

The average Shannon diversity was 3.01 and ranged between 2.49 and 3.82. The average diversity was low (H = 2.55) in *Olea -Dodonea –Micromeria* association and high (H = 3.29) in *Pinus-Diospyrus–Myrsine*. The average species richness was 4.90 ranged between 3 and 7.01. The richness was low (R = 3.24) in *Olea-Dodonea-Micromeria* association and high (R = 5.50) in *Pinus-Oxalis-Dactylis* association. The altitude was significantly positively correlated with diversity and richness and explains


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21% variation in diversity and 19% in richness. Average Evenness was 0.63 ranges between 0.46-0.72. Average equitability was 0.86 and ranged between 0.93-0.91. All the forest stands was immature as the maturity value is less than 60% (*Table 2*).

***Table 2.*** *Diversity and its components recorded from Tehsil Harighel*

| Association | Communities | Altitude (m) | Species number | Diversity (H) | Richness (R) | Evenness (G) | Equitability (E) | Maturity (M) |
|---|---|---|---|---|---|---|---|---|
| *Olea-Dodonea-Micromeria* | *Olea-Dodonaea-Pinnisetum* | 980 | 17 | 2.49 | 3.00 | 0.715 | 0.88 | 33.92 |
| | *Olea-Micromeria-Dodoneae* | 1165 | 23 | 2.62 | 3.55 | 0.63 | 0.85 | 31.39 |
| | *Olea-Aegopodium-Dryopteris* | 1340 | 21 | 2.54 | 3.17 | 0.60 | 0.83 | 37.39 |
| | | | | **2.55** | **3.24** | **0.64** | **0.85** | **34.23** |
| *Pinus-Oxalis-Dactylis* | *Dactylis-Pinus-Myrsine* | 1079 | 34 | 2.74 | 4.93 | 0.47 | 0.78 | 30.44 |
| | *Pinus-Olea-Galium* | 1240 | 48 | 2.97 | 7.01 | 0.71 | 0.91 | 24.78 |
| | *Pinus-pinus-Wikstroemia* | 1658 | 28 | 2.97 | 4.56 | 0.72 | 0.90 | 35.92 |
| | | | | **2.89** | **5.50** | **0.63** | **0.86** | **30.38** |
| *Pinus-Diospyrus-Myrsine* | *Pinus-Oenethera-Trifolium* | 1450 | 30 | 3.82 | 4.50 | 0.56 | 0.83 | 34.55 |
| | *Pinus-Fragaria-Sarcococca* | 1554 | 38 | 2.96 | 5.30 | 0.55 | 0.83 | 40.61 |
| | *Diospyros-Pinus* | 1760 | 40 | 3.19 | 5.32 | 0.67 | 0.88 | 41.05 |
| | *Pinus-Quercus-Galium* | 1864 | 35 | 3.20 | 5.64 | 0.65 | 0.881 | 32.95 |
| | *Pinus-Micromeria-Quercus* | 1964 | 36 | 3.33 | 6.23 | 0.64 | 0.88 | 41.42 |
| | *Pinus-Adiantum-Quercus* | 2052 | 43 | 3.27 | 5.61 | 0.65 | 0.88 | 34.49 |
| | | | | **3.29** | **5.43** | **0.62** | **0.87** | **37.52** |

## Discussion

Plant associations reflect the environmental condition under which they develop (Malik, 1986; Ilyas et al., 2015). The climate of Tehsil Harigal is of subtropical and


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temperate type (Shaheen et al., 2011a,b; Malik and Malik, 2012) but marked difference in microclimatic, topographic and edaphic factors lead to the establishment of three different plant association with respect to the floristic element and micro environmental conditions. The spatial distribution of plant species in these associations were controlled by different environmental factor like altitude, topography and physcio-chemical properties of soil. The micro gradient established due to variation and interaction among these factors result in different type of vegetation (Hanson and Churchill, 1965) DCA and CCA analysis clearly reflect that altitude and phsico-chemical properties of soil are the main governing factor in the distribution pattern of plant species. This was strongly supported by Ahmad et al. (2009); Shaheen et al. (2012), Amjad et al. *(*2014 b), Ilyas et al., (2015), Rahman et al. (2016) and Sadia et al. (2017). The large scale pattern in species distribution and physiognomy is mainly governed by climate but physico-chemical properties of soil also govern the distribution pattern on local or micro level (Bakkenes et al., 2002). Climate can be characterized by different variable mainly available moisture which mainly determines the distribution pattern (Leeman and Cramer, 1991). The moderate rainfall and high temperature of Tehsil Harigal result in the stratified forests. Soil is key factor that play important role in selection of plant by bringing evolutionary changes (Barbour et al., 1980). The vegetation of particular area has strong relationship with the soil (Ali et al., 2004). The physico- chemical properties are directly related to soil depth which play key role in establishment of plant association or communities (Khan et al., 2013) The Electrical conductivity of soil of *Olea-Dodonea-Micromeria* association was high whereas organic matter, pH, available moisture nutrient content as compared to *Pinus-Oxalis-Dactylis* association and *Pinus-Diospyros-Myrsine* association which result in establishment of different vegetation type. Slight differences in the available nutrients are positively correlated with variations in community structure (Noor and Khatoon, 2013).

Species diversity is reflection of the health and productivity of ecosystem. Diversity was low in the investigated area due to heavy grazing, deforestation, road construction and fuel wood extraction etc. (Ram et al., 2004; Kumar and Bhatt, 2006). The species diversity and richness was high in *Pinus-Diospyrus–Myrsine* association which might be due to number of coexisting and interacting plant species having overlapping niche (Saxena and Singh, 1982). Moreover the site of higher altitude (*Pinus-Diospyrus–Myrsine* association) are difficult to access by local inhabitant which also resulting high species diversity and richness. The species richness and diversity is positively correlated with altitude. Our findings are in accordance with Malik and Malik (2012) who reported positive correlation between diversity and altitude which might be due to increase in humidity. Differences in altitudes, aspects and slopes result in variation in species diversity and association types. The plant communities harboured at North facing slopes have high diversity with thick vegetation because of high moisture content on southern slope as compared to north facing slope. The same results were obtained by Khan et al. (2011); Amjad et al. (2014a) and and Haq et al. (2015). Plant growth and survival can be affected by amount of water runoff and infiltration which is dependent upon position and smoothness of slope. Aspect and steepness of slope affect the amount of solar radiation which in turn affect temperature on the ground surface (Sukopp and Werner, 1983) and the amount and type of soil accumulated (Monsen et al., 2004). The evenness and equitability is intermediate due to the long term stable climatic condition and uniform pattern of species distribution in majority of plant communities in Harigal. The maturity index reflects immature forest structure throughout investigated area because


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plant species were less adapted to microclimate. The natural balance of plant communities was disturbed due to high anthropogenic pressures which further enhance this pattern (Saxena and Singh, 1982; Shaheen et al., 2011a).

## Conclusion

The current study suggests that environmental gradient has profound influence on the distribution of plant species in Tehsil Harighel and association of plant change due to change in environmental variable. Further low value of species diversity and associated indices reflects deteriorating forest structure due to immense anthropogenic pressure in the form of intense grazing, severe deforestation for fuel, fodder and construction purpose, trampling and road construction etc. Therefore immediate conservations measures are needed to preserve the rich plant species diversity of these degraded forests. Land use mapping and vegetation assessment using modern software like ERDAS, arc GIS and NDVI, and are also recommended.

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