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RESEARCH ARTICLE

Multivariate analysis and vegetation mapping of a biodiversity hotspot in the Hindu Kush Mountains

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Abstract

To explore and understand the floristic composition of one of the most important biodiversity hotspots in the Hindu Kush region of Pakistan, a multivariate analysis of species was carried out using the DCA and CCA ordination methods. Ordination plots were developed to evaluate interaction between tree-tree, tree-herbaceous plants and plants-environmental variables, using Canoco 4.6 for Windows. Results obtained for the DCA analysis of the tree species only indicate that *Taxus baccata* has the lowest correlation response with the other species and thus forms no association with the other native trees like *Picea smithiana*, *Cedrus deodara* and *Abies pindrow*. The DCA results for the locations-only data indicate that location 18 (Sulatanr and Rodingar) provides distinct microclimatic conditions for the flora and can be termed as the superior biodiversity hotspots of the area. Results also indicate that all the lowland species have positive correlation response to rock, water bodies, field (Farms) and unpaved paths and are closely associated with each other. Different tree species or group of species were found to support specific sub-flora while species i.e. *Pinus roxburghii* was found to be ecologically associated with no immediate sub-flora. It was observed that this species of Pine is the favourite plant used for re and afforestation purposes in the area. It is recommended that the species selection for the reforestation efforts should be revisited, and the impact of the climate change should be evaluated on these species if the ultimate aim of these projects is to improve the forest services and biodiversity of the area.

INTRODUCTION

Biodiversity is defined as “the kinds and number of organisms and their patterns of distribution” (Barnes et al. 1998). It can be expressed in simple terms as “species richness” (Simberloff, 1999), and can be further classified into static and dynamic biodiversity (Wohlgemuth et al. 2002). Recently, the term biodiversity has been very widely used in connection with ecological sustainability and conservation studies (Schuler 1998; Swindel et al. 1984). The term Functional Diversity (FD) is probably the recent modification to the original word, which has in fact no clear definition (Petchey and Gaston 2006) but according to Tilman (2001) and Petchey and Gaston (2002), functional diversity is the measure of extent of functional trait variation among communities. While, according to Daiz et al. (2007) it is the measure of kind, range and relative abundance of traits (i.e. similarity/dissimilarity).

Species identification and quantification (biodiversity analysis) is an important approach in conservation ecology (Kent and Coker, 1996), and predominantly biodiversity measurements are carried out at species-level, but can be adjusted for diversity evaluation at different scales (Ardakani 2004; Eshaghi et al. 2009). In order to understand the biodiversity of an area or a region, units of population ecology must be recognised. Community is the assemblages of a functional unit of species in spatial and temporal terms (Magurran, 1988) and generally these assemblages can be classified into different groups, which provide bases to the Vegetation Science (Kashian et al. 2003). The classification of plant communities is mainly based on the floristic composition and the presence of indicator species. However, rapid growth in human population and their settlement on new lands are the overriding factors responsible for the exploitation of the plant communities which lead to vanishing most of the forests and the introduction of exotic and alien species.

The rate of global loss of forests between 1990 and 1997 was 5.8 ± 1.4 million hectares annually only from the tropical forests (Achard et al. 2002) and the rate of deforestation is still on the rise at an alarming rate (Fearnside, 2005). This act has created severe competition for the native species and imbalance in the species richness (Wallis De Vries et al. 2002).

Pakistan, unfortunately, has only 4.5% forested area of the total geographical area, in comparison to 20 to 80% elsewhere (Khan et al. 2013) and even worse these patchy forests have rarely been studies systematically and so far very little is known about their full floristic composition, structure, dynamics and the overriding factors responsible for its deterioration (Ahmed et al. 2011).

To explore and understand the floristic composition of one of the most important biodiversity hotspots in the Hindu Kush region of Pakistan, a multivariate analysis of species was carried out using the DCA and CCA ordination methods. District Swat is a remote valley of Pakistan and was chosen for the research as it is considered the most important biodiversity hub of the country providing invaluable medicinal and aromatic plants to national and international markets (Ali, 2015; Khan et al. 2015, Ali et al. 2014, Ahmed et al. 2011). It is therefore, imperative to understand the floristic composition of the area to promote sustainable use of the bio-ecological resources (Ali et al. 2013). A multivariate analysis of species was carried out using the DCA and CCA ordination methods. Ordination plots were developed to evaluate the interaction between tree-tree, tree-herbaceous plants and plants-environment using Canoco 4.6 for Windows. The aim of the research was to comparatively assess the different plant communities of the Valley in order to understand the current and future risks to the biodiversity of the area and investigate possible solution to the problems. Up-to-date, limited methods have been applied to understand the biodiversity of the area, predominantly floristic inventories have been developed using ordinary sampling techniques and simple statistical analysis and (Khan et. al. 2014). The current study was designed to help in understanding the vegetation composition of the area using multivariate techniques to compare the association of plants amongst themselves and their interactions with their surrounding physical environment. The results of the present study will provide a baseline data for further studies in conservation and management of the area and can help the authorities in making better decisions towards the future forest management policies.

Materials and Methods

In ecology and phytosociology, many different methods are in use for data collection and analysis and all these methods have their pros and cons. Generally, the quadrat method of data collection is preferred (Kent and Coker 1996) which was chosen for the data collection in this investigation. The species presence data from the selected plots belonging to 23 different localities (Locations, represented as L1-23) of District Swat was collected. The Quadrat size of 100 x100m was used for the tree count and small 5x5 metres for the herbaceous sub-flora, as variation in the sampling size is allowed (Kent and Coker 1996). For all the plots (quadrats), geographical position system (GPS) data was recorded alongside other metadata, i.e. aspect, elevation and slope etc. using DX-GPS system of RedHen technology.

The extracted metadata in the form of CSV comma delimited text file format which was then converted into MS Excel sheets, imported into ArcMap 10 and transformed into Canoco 4.6 format (Ter Braak and Smilauer, 2002). The species density data collected from the selected plots was first transformed into binomial (presence/absence) data, which is one of the preferred methods (e.g. Smith, 1983) for ordination and vegetation classification. After data transformation, the following two methods of ordination analysis were carried out using Canoco 4.6 for Windows (Ter Braak and Smilauer 2002):

- Detrended Correspondence Analysis (DCA) and
- Canonical Correspondence Analysis (CCA)

The DCA technique was used to evaluate similarities/differences between the floristic compositions of the vegetation samples, while the CCA ordination analysis method was performed to establish the relationship of the floristic data to the environmental data i.e. elevation, path/un-paved roads, water body, forests, boundary, field/farm and rock. The ordination results were presented in the form of ordination graphs/plots.

Results

The results obtained were categorized and presented in the following order.

The DCA analysis for trees only data

The DCA ordination diagram for tree species-only data indicates that *Taxus baccata* being at the top right corner of the ordination plot has a unique set of gradient and thus does not share its habitat with any other tree species. *Picea smithiana* and *Abies pindrow* are positioned below *Taxus baccata* in a vertical symmetry show a good association amongst eachother and prefer moderately high altitude (Figure 2). Description of species names and location data is provided in Table 1 and Appendix 1 and 2 respectively.

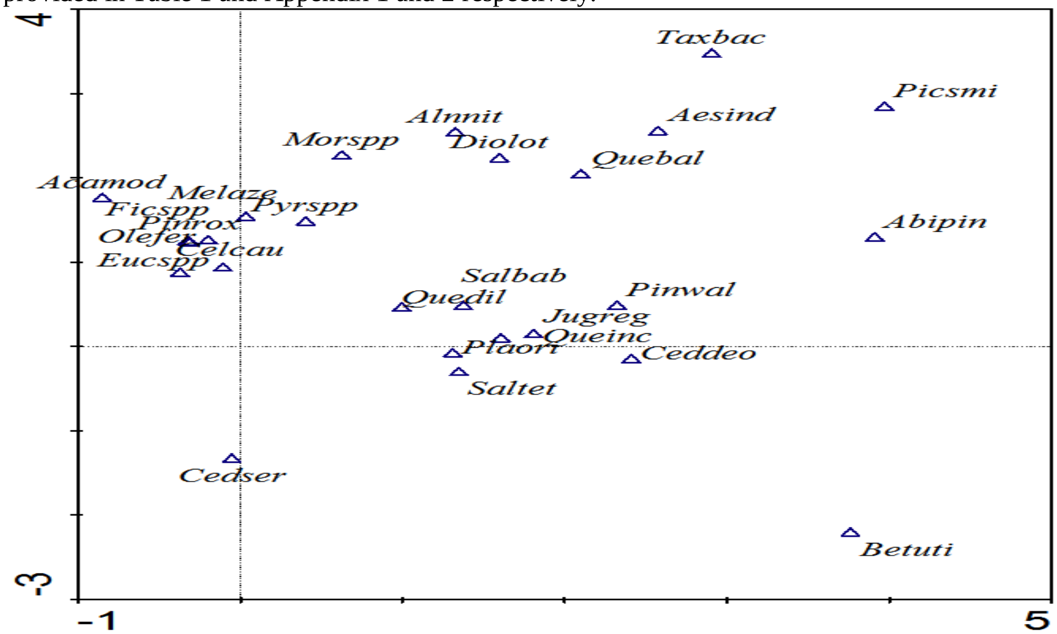

Figure 1. DCA ordination plot for trees only (for species names and codes see Appendix 1 and 2)

A distinct group of plants i.e. *Acacia modesta, Olea ferruginea, Melia azedarach* and *Euclyptus* spp. can be observed clustered together to the left hand side of the ordination plot, suggesting that they all share the same environmental conditions in the study area and thus have close association with each other (see Figure 1). The DCA ordination plot for the locations only data indicates that Location 18 (Sulatanr and Rodingar) provides a set of distinct environmental conditions for the flora and thus is plotted at the top right hand corner of the ceanospace. On the other hand Location 15 (Kalam, Chirat Kalam, Matiltan and Maho Dand) is plotted at the bottom of the ordination plot, suggesting that this location has some unique climatic regime, contrasting to location 18. Locations 16 (Miandam proper), 17(Beshigram) and 20 (Lalkoh) are similarly ordinated together in the right hand side of the ordination plot, suggesting similar vegetation type and floristic composition (see Figure 2). Some closely clustered locations are 1, 2 3, 4, 5 6, 7, 8, 9, 11, 12 and 23 (for location names see Table 1 and for the species names and codes refer to Appendix 1 and 2).

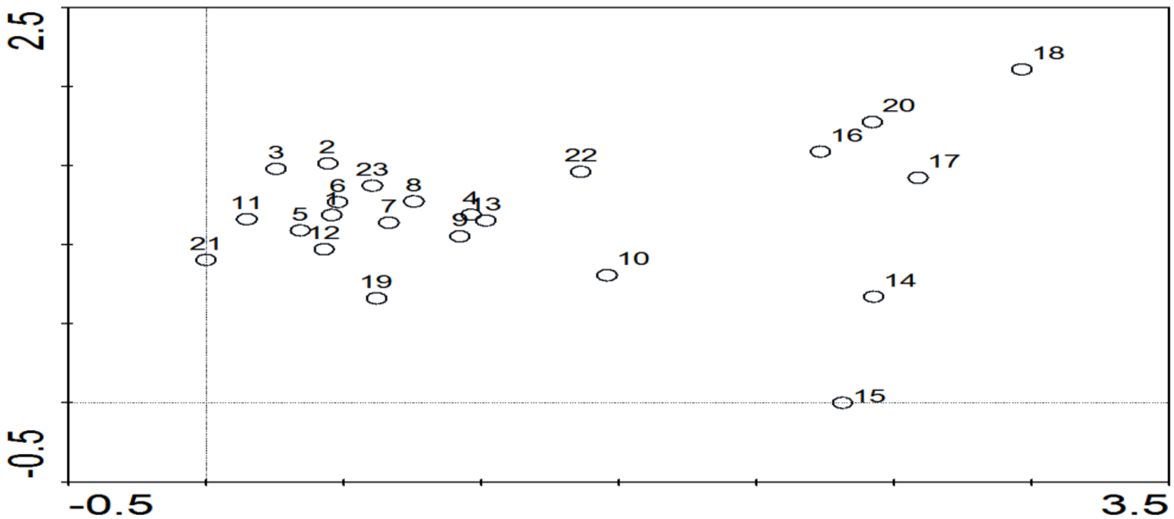

Figure 2. DCA ordination plot for locations only

Table 1. The selected locations and their codes

Code	Place names
L1	Landakay, Kota, Aboha, Gwaratai, Barikot
L2	Nawagai, Krakar, Krakar Road, Karakar boundry
L3	Shingardar, wayna, Ghalegay, Odigram, Qambar, Amankot, Dandono qala, Pajingram, Balogram
L4	Aqba, Saidu Sharif
L5	Goligram, Mian baba, Kokrai
L6	Islam Pur, Khadra Islampur
L7	Fateh Pur
L8	Spal Bandai, Marghazar Road, Gul bandai, Grave yard, Mairagai, Mayna, Amluk tal, Tarkana
L9	Marghazar proper
L10	Jawzo sar Marghuzar
L11	Shagai, Chail Shagai, Serai Shagai, Baligram
L12	Doup Islampur
L13	Marghuzar ranzaro sar, Sher Atraf
L14	Mankial, Sur Karn Mankial, Jaba Mankial, Koz Jaba, Badi Baba
L15	Kalam, Chirat Kalam, Matiltan, Maho dand
L16	Miandam proper
L17	Beshigram
L18	Sulatanr, Rodingar
L19	Kabal and the surrounding

L20	Lalkoh
L21	Ningwalai, Sher palam, Asharay
L22	Topsin, Malam Jaba
L23	Sangar, Jambil, Kokarai

The other locations i.e. Location 20, 14, 10 and 19 are scattered in the middle of the plot in the positive ceonospace of the plot and suggesting a shared Phyto-ecological composition.

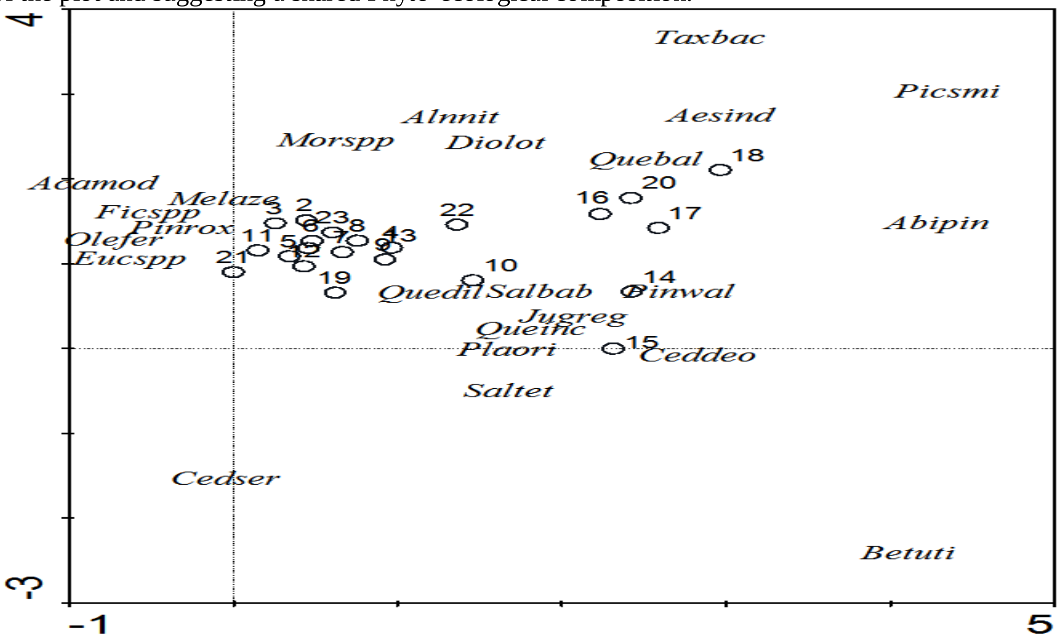

Figure 3. DCA ordination plot for locations and tree species

The DCA biplot of the locations and tree species reveals the same results described for Figure 2 and 3. It is evident that Location 18 (Sulatanr, Rodingar) Location 20 (Lalkoh) and Location 16 (Miandam proper) share some of the important tree species and are thus clustered together in the plot with their corresponding species (Figure 3).

DCA ordination analysis for herbaceous plants

The DCA plot of the herbaceous species only data shows that most of the herbs were plotted scattered in the plot with few plants like *Paeonia emodi*, *Aconitum heterophyllum*, *Myrcine africana* in the top tier of the plot while *Rumex hastatus*, *Sorberia tomentosa*, *Plantago lanceolata* were plotted at the lower end of the plot (Figure 4). The Figure 4 was originally very crowded as 136 herbaceous species were plotted simultaneously, which were reduced to only important species of the area.

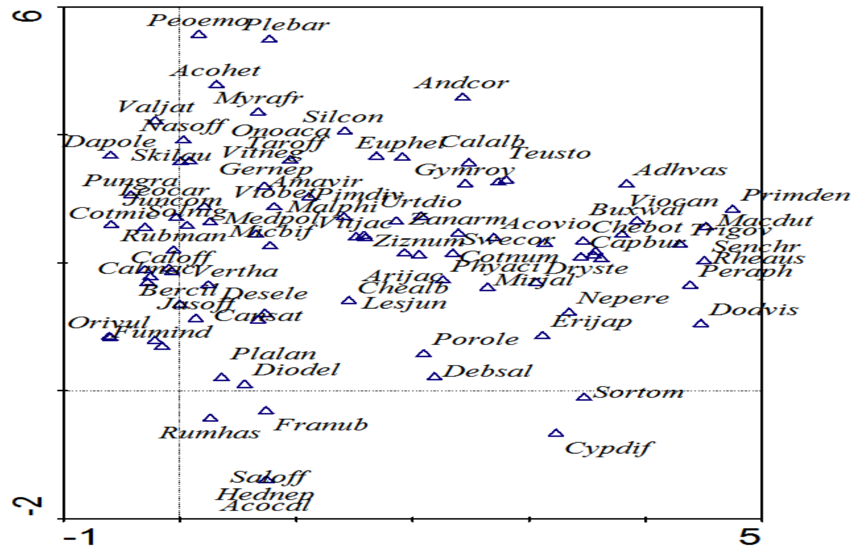

Figure 4. DCA ordination plot of the herbs only data

The DCA ordination biplot for herbaceous species and locations and the scattered plot for location-only data were also created. Location 10 (Jawzo Sar Marghuzar) is plotted at the top of the ordination diagram, suggesting that this location has a unique floristic constitution not very dissimilar to that of location 11 (Shagai, Serai Shagai and Baligram). Locations 16 (Miandam), 17 (Beshigram) and 20 (Lalkoh) sharing similarities in the vegetation structure and were therefore plotted in the extreme right of the plot. These Locations share a number of tree and herbaceous species evident from Figure 4 and 5.

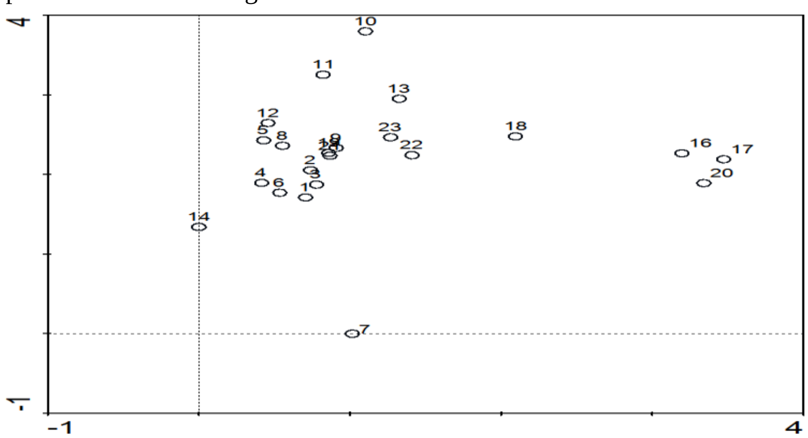

Figure 5. DCA ordination plot for the locations only data

CCA analysis of the tree species and the environmental disturbance regime

The CCA ordination results obtained were not significantly different from the DCA results. By observing Figure 7, it can be instantly noticed that locations 10 and 20 have been placed as unique in terms of their species interactions and biodiversity and in total contrast to each other. In the CCA analysis, Location 16, 17, 19 and 21 were clustered together as a group of having similar characteristics (see Figure 6). Locations 12, 13, 14, and 15 were clustered together at the top of the ordination plot, suggesting that they share the same flora under similar environmental gradient and disturbance regime (Figure 6). The environmental variables were masked out from this plot, for the sake of clarity.

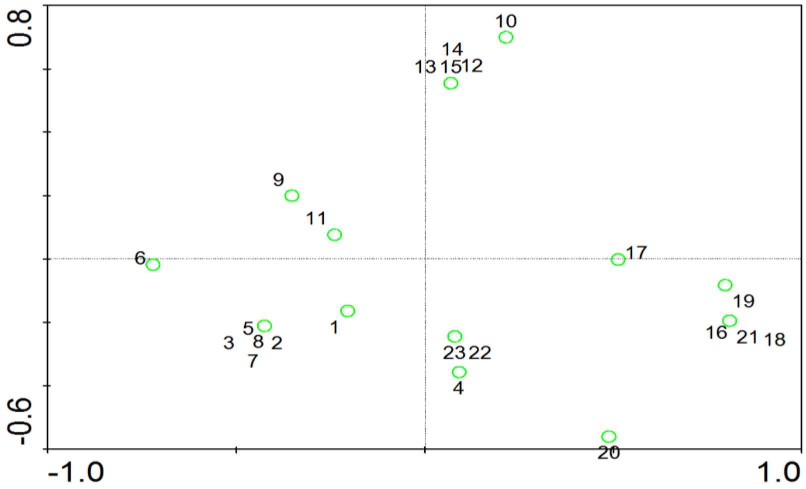

Figure 6. CCA ordination plot of the locations using disturbance factors

The results from the triplot of the ordination diagram can be interpreted for *Betula utilis* being an outlier plotted at the very top of the plot or a species of having no similarities with any of the other plants and having restricted appearance in the observed locations. The tree species like, *Picea smithiana* and *Taxus baccata* were still found to be closely associated showing similar gradient requirements for their growth and reproduction. As a common observation during data collection phase, *Taxus baccata* has always been recorded at high altitudes near the tree line and close to the forest boundaries. This is also evident from the ordination diagram that this species has a great affinity to the high altitudes and the forest boundaries.

The CCA analysis of trees and environmental data

It is very clear from Figure 7 that all the lowland species i.e. *Acacia modesta, Euclyptus spp, Morus spp, Olea ferruginea* and *Alnus nitida* are plotted on the negative ceanospce of the plot but are having positive correlation response to rock, water body, field, and paths. The biplot also explains the nature of the gradients at Location 1 being a farm land and having un-paved roads and pathways (Landakay, Kota, Aboha, and Barikot) (see Figure 7).

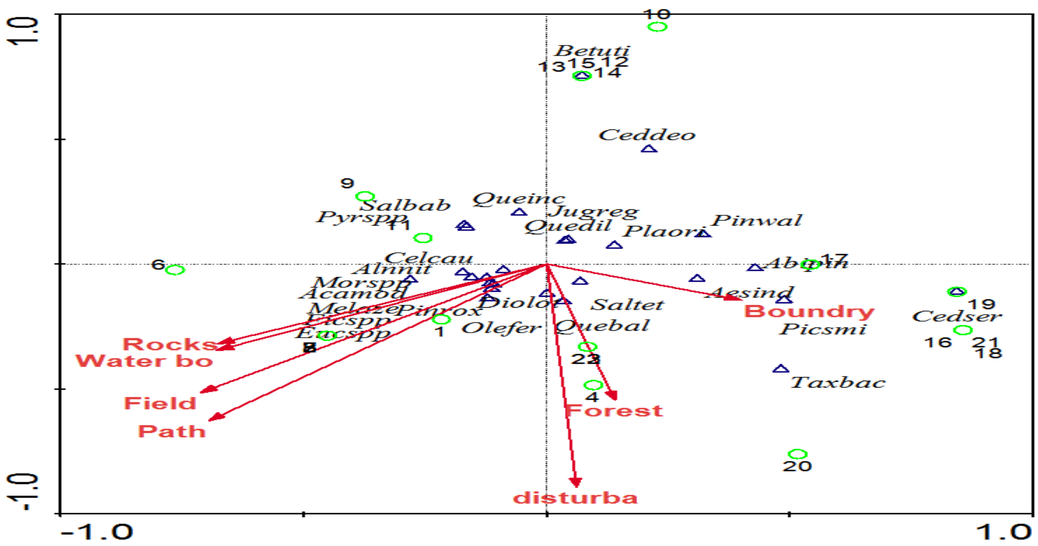

Figure 7. CCA ordination triplot for tree species, environmental variables and Location data

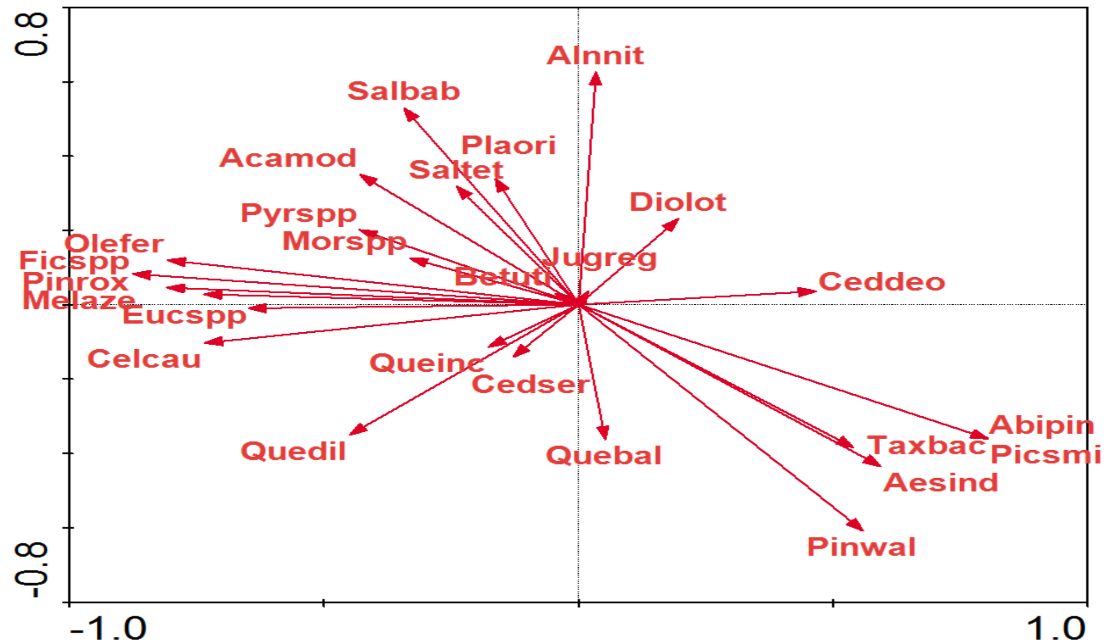

Figure 8. CCA ordination plot for herbaceous species, tree data used as environmental variables; for the species names and codes see Appendix 1 and 2

The CCA analysis for the herbaceous plants using tree species as environmental variable was also carried out. The response of the different tree species on the distribution of the herbaceous species was tested. *Pinus wallichiana* was found to be associated with no immediate subflora albeit; it is normally a species of choice for the reforestation efforts in the area. Species like *Abies pindrow, Pinus wallachiana* and *Picea smithiana* were closely associated and supports similar sub-flora (Figure 8 and 9). All *Quercus* species were found to have similar response in the ordination plot and support many species of the subflora (Figure 9).

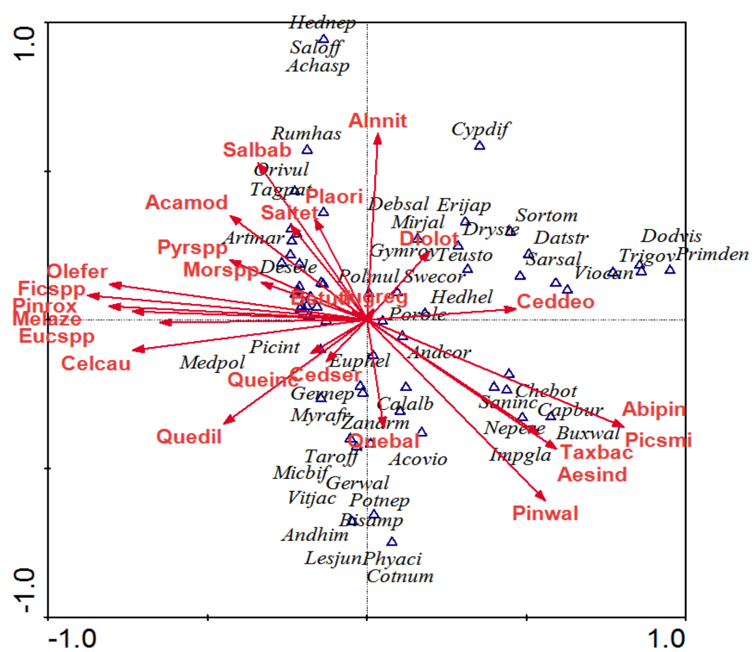

Figure 9. CCA ordination triplot for herbaceous species; the tree species data was used as environmental variables (for species names see Appendix 1 and 2)

Results related to the CCA ordination analysis using altitude as the only environmental variable show that altitude has a clear effect on most of the species. Species plotted on the left side of the ordination plot have clearly negative correlation with the altitude while the other group of plant species on the right hand side of the plot has positive correlation with the altitude (Figure 10). Species like *Betula utilis*, *Pinus wallichiana*, *Abies pindrow*, *Aesculus indica* and *Quercus incana* all prefer to grow above the average altitudes in the Valley (Figure 10).

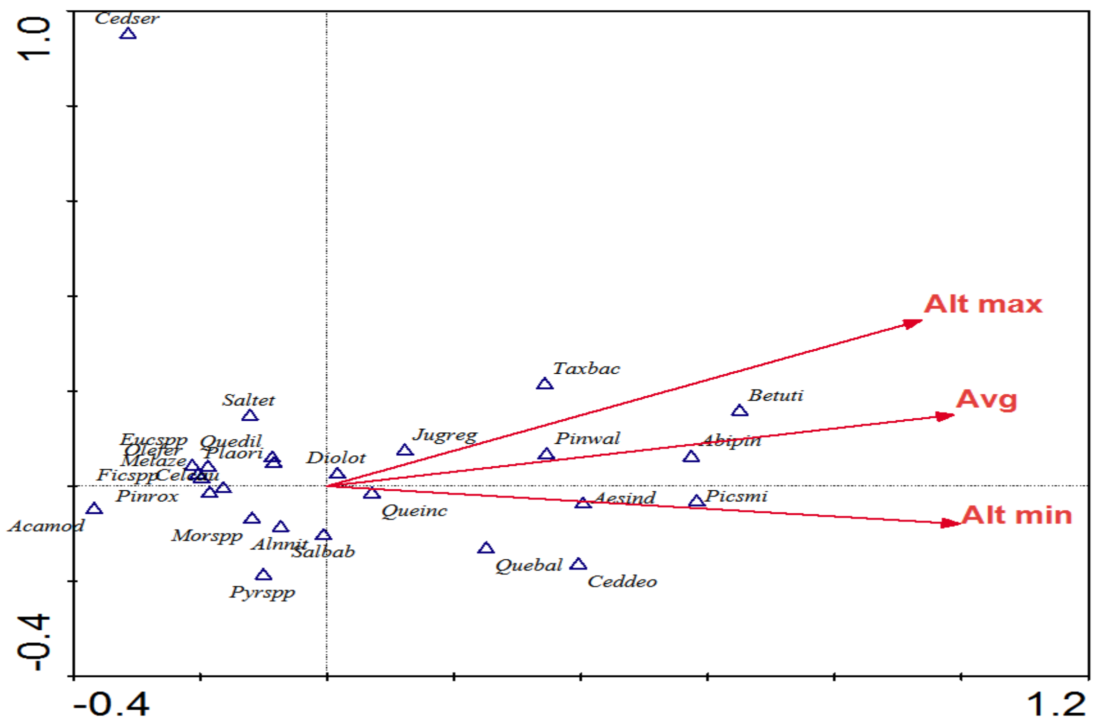

Figure 1. CCA ordination biplot for altitude and tree species (for species names see Appendix 1 and 8)

On the other hand, species like *Euclyptus spp. Olea ferruginea*, *Morus spp.*, *Ficus spp. Pinus roxburghii*, *Pyrus spp*, *Alnus nitida and Salix babylonica* prefer low altitude, and are plotted on the left side of the ordination biplot. The scattered plot for CCA using altitude as the only environmental variable clearly differentiated two distinct groups of locations. All locations of high altitudes were plotted on the right, while all low altitude locations are plotted on the left side of the ordination plot (Figure 11 and for location names see Table 1).

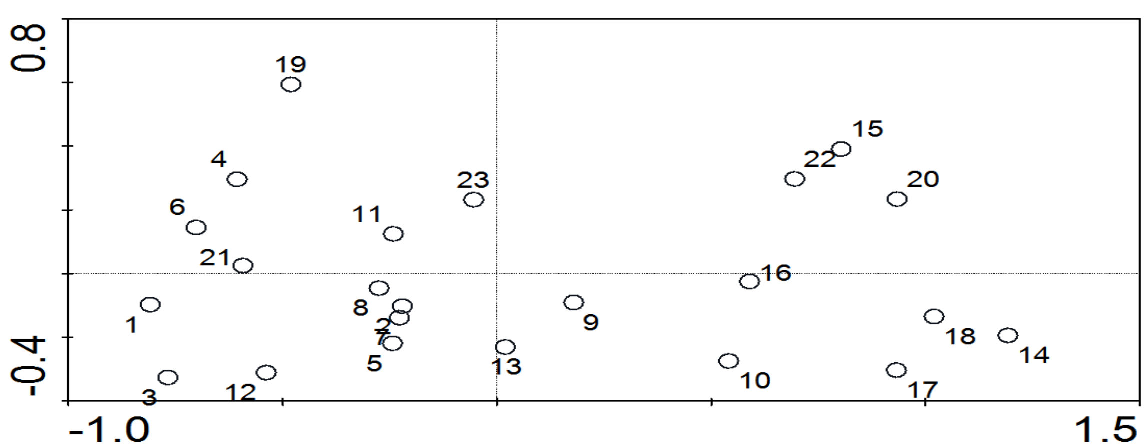

Figure 11. CCA for herbs using elevation data as the environmental variable

The response of altitude for herbaceous species was also assessed using CCA ordination method. The herbaceous species at the right hand side of the plot prefer high altitudinal niches while those plotted on the bottom left have negative correlation for high altitudes. It is very obvious from Figure 12 that many species prefer to grow in the optimum altitude, as they are getting the required abiotic or biotic stimuli at this altitude. In the herbaceous flora, *Micromeria biflora, Berberis lyceum* were the plants of high altitudes of the Valley (see Figure 12).

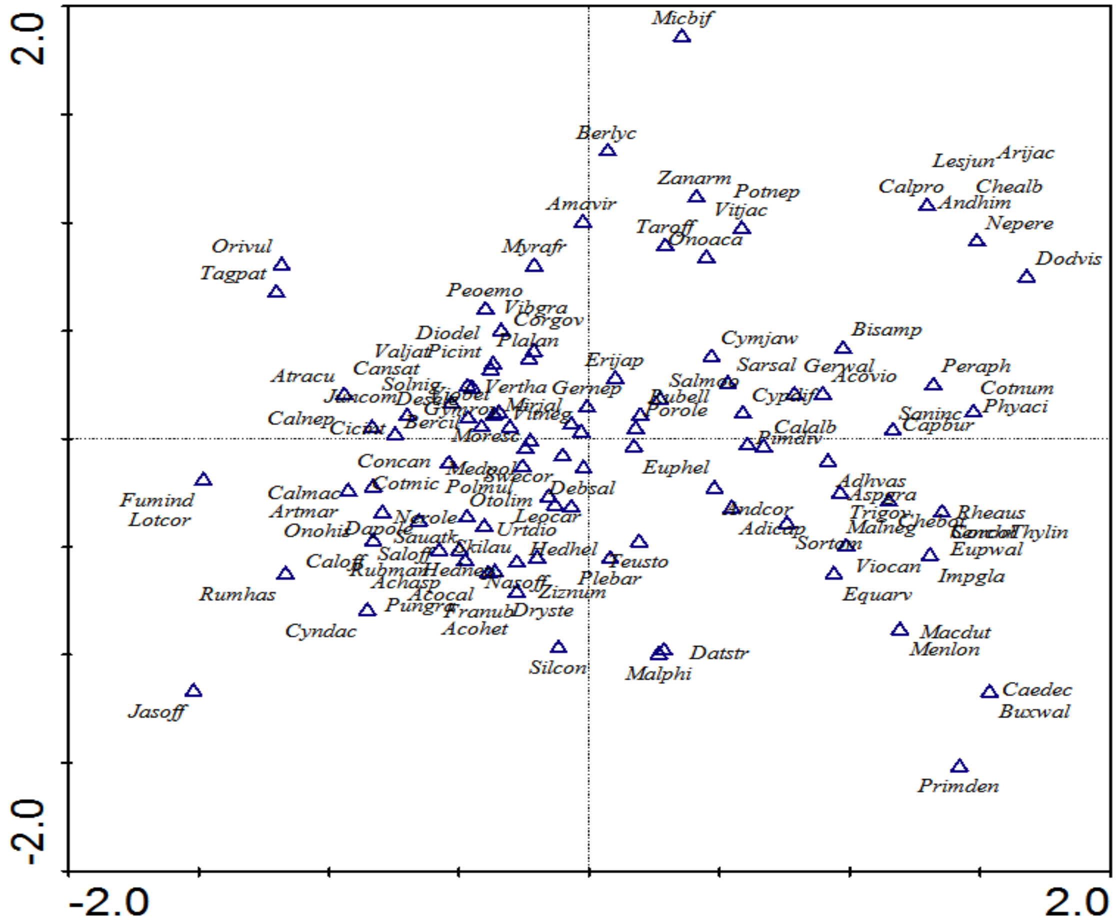

Figure 12. CCA ordination plot for herbaceous species using altitude as environmental variable (for species names see Appendix 1 and 2).

Species like, *Rumex hastatus*, *Fumaria indica, Artemisia maritima*, etc. are those herbaceous plants which prefer to grow on the low altitudes and are therefore clustered together at the left side of the plot near the optimal line of the ordination plot (Figure 13).

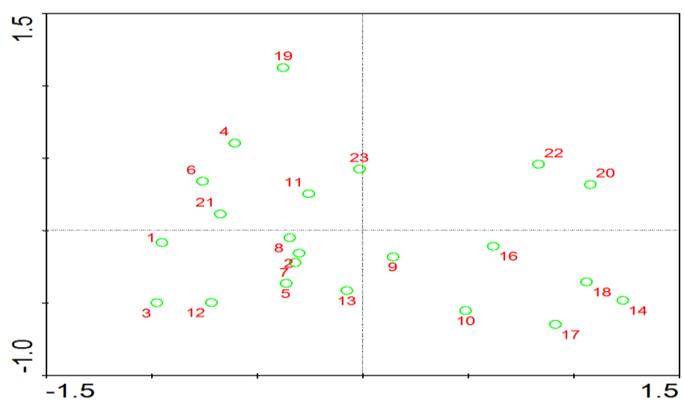

Figure 13. CCA ordination diagram of Locations, using altitude as environmental variable

Discussion and conclusions

In conclusion, the DCA ordination diagrams have revealed a very close association of some of the tree species amongst each other, for example, *Picea smithiana* and *Abies pindrow were found in close association*, suggesting that these species are effected simultaneously in almost an equal manner and intensity by the available biotic and abiotic factors. It can also be concluded that altitude play a vital role in the distribution of these species in the study area. This phenomenon has already been observed by Rahbek (1995) and Zhao et al. (2006) in other parts of the world for similar species. The current study's findings are also in agreement with Gottfried et al. (1998), who have clearly indicated the effect of biodiversity at different altitudinal variations using GIS and CCA ordination techniques in other part of the world.

All the species forming clusters in the DCA plots must be growing at the same altitudinal range, this group of trees in the Valley was composed of *Morus spp.*, *Olea ferruginea, Melia azedarach* and *Euclyptus* spp. Furthermore, the DCA ordination analysis has revealed that some locations have very peculiar vegetation and thus can be confidently termed as their indicator species. These particular locations were identified as: Location 18 (Sulatanr and Rodingar), Location 15 (Kalam, Chirat Kalam, Matiltan and Maho Dand), Location 16 (Miandam proper), Location 17 (Beshigram), and Location 20 (Lalkoh). These are the locations known for their great tourist attractions and are famous for their lush greenery. This classification and distinction of locations could also mean that more attention is needed for the conservation of these sites and stricter legislations and regulations are needed to make these areas safe form exploitation.

The CCA ordination results obtained were not significantly different from that of the DCA. The CCA analysis using the tree species as environmental variables, clearly show a pattern of trees-subflora interaction. Some subflora is very closely associated with the upper canopy tree species, and the loss of these tree species can have devastating effects on the sub-story herbaceous flora. There remains a serious threat to the MAPs industry of the area from deforestation, which ultimately will have serious impact on the socioeconomic situation of the area. It was found that *Pinus roxburghii* population does not support any significant sub-flora, albeit, this is the species used for the reforestation purposes in the area. This concept of monocultural afforestation/reforestation practices must be extensively studied to understand the association of the trees and sub-flora and to establish reasons for the lack of the sub-flora. There could be any possible reason for the absence of the subflora under the *Pinus roxburghii* canopies, i.e. allelopathy, etc. and warrents further investigation. Some distinct categorization of the plant species and plant communities can be done by using altitude as the only climatic variable. The results obtained suggest that altitude as an environmental variable clearly differentiate two distinct groups of locations. As a general rule herbaceous plants can be divided into high altitude lovers and low altitude lovers. Plants i.e. *Micromeria biflora*, *Berberis lyceum* normally grow in association with *Picea smithiana* and *Abies pindrow*, prefer to grow at high altitudes while *Rumex hastatus*, *Fumaria indica*, *Artemisia maritima* will grow in association with the lower altitude trees. It is recommended that the species selection for the reforestation efforts should be revisited, if the ultimate aim of these projects is to improve the forest services and biodiversity in the area. The climate change impact on these plants should be evaluated in order to conserve the valuable flora of the area for the future generations.

Appendix 1

Plant Species	**Code**
Achyranthes aspera L.	*Achasp*
Adiantum capillus-veneris L.	*Adicap*
Debregeasia salicifolia (D.Don)	*Debsal*
Eriobotrya japonica (Thunb.) Lindle.	*Erijap*
Punica granatum L.	*Pungra*
Bistorta amplexicaulis (D.Don) Green.	*Bisamp*
Euphorbia wallichii Hook.f.	*Eupwal*
Impatiens glandulifera Royle	*Impgla*
Rubus ellipticus Sm.	*Rubell*
Viola canescens Wall. ex Roxb.	*Viocan*
Equisetum arvense L.	*Equarv*
Cannabis sativa L.	*Cansat*
Periploca aphylla Dcne.	*Peraph*
Atropa acuminata Royle ex Miers	*Atracu*
Prunus cornuta (wall.ex.Royle)	*Prucor*
Plectranthus barbatus Andrews	*Plebar*
Cymbopogon jawarancusa (Jones) Schult.	*Cymjaw*
Adhatoda vasica Nees	*Adhvas*
Calamintha nepeta (L.) Savi.	*Calnep*
Ajuga bracteosa Wall. ex Benth	*Ajubra*
Amaranthus viridis L.	*Amavir*
Viburnum grandiflorum Wall. ex DC.	*Vibgra*
Swertia cordata Wall.	*Swecor*
Rheum australe D.Don	*Rheaus*
Conyza canadensis (L.) Cronquest.	*Concan*
Rumex hastatus D.Don	*Rumhas*
Fragaria nubicloa (Hook.f.) Lindl.	*Franub*
Zanthoxylum armatum DC.	*Zanarm*
Datura stramonium L.	*Datstr*
Corydalis govaniana Wall.	*Corgov*
Cyperus difformis L.	*Cypdif*
Euphorbia hirta L.	*Euphir*
Lotus corniculatus L.	*Lotcor*
Nerium oleander L.	*Nerole*
Onosma hispidium Wall.	*Onohis*
Silene conoidea L.	*Silcon*
Dodonea viscose L.	*Dodvis*
Indigofera heterantha Wall.ex Brand.	*Indhet*

Juniperous communis L.	*Juncom*
Morchella esculenta (L.) Pers. ex Fr.	*Moresc*
Mirabilis jalapa L.	*Mirjal*
Rosa indica L.	*Rosind*
Agrimonia eupatoria L.	*Agreup*
Tagetes patula L.	*Tagpat*
Cichorium intybus L.	*Cicint*
Iris hookeriana Foster	*Irihoo*
Plantago lanceolata L.	*Plalan*
Caesalpinia decapetala (Roth) Alston	*Caedec*
Artemisia scoparia Waldst. & Kit.	*Atrsco*
Cynodon dactylon (L.) Pers.	*Cyndac*
Podophyllum emodi Wall. ex Royle	*Podemo*
Solanum nigrum L.	*Solnig*
Berginia ciliata (Haw.) Sternb.	*Bercil*
Mallotus philippensis (Lam.) Muell.Arg.	*Malphi*
Zizyphus nummularia (Burm.f.) Wight & Arn.	*Ziznum*
Rubus fruticosus agg.	*Rubfru*
Teucrium stocksianum Boiss.	*Teusto*
Callicarpa macrophylla Vahl.	*Calmac*
Verbascum thapsus L.	*Vertha*
Salvia moorcroftiana Wall. ex Benth.	*Salmoo*
Andrachne cordifolia Wall. ex Decne	*Andcor*
Potentila nepalensis Hook.	*Potnep*
Berberis lycium Royle	*Berlyc*
Sarcococca saligna (D.Don) Muell. Arg.	*Sarsal*
Daphne oleoides Schreb.	*Dapole*
Vitex negundo L.	*Vitneg*
Caltha alba Jacq. ex Comb.	*Calalb*
Viola betonicifolia Sm.	*Viobet*
Peonia emodi Wall. ex Royle.	*Peoemo*
Cotoneaster nummularia Fish. & Mey.	*Cotnum*
Primula denticulata Smith.	*Primden*
Thalictrum falconeri Lecoy.	*Thafal*
Euphorbia helioscopia L.	*Euphel*
Machilus duthiei King ex Hook. f.	*Macdut*
Tribulus terrestris L.	*Triter*
Myrsine africana L.	*Myrafr*
Valeriana jatamansi Jones	*Valjat*

Micromeria biflora (Buch-hamp ex D.Don) Benth.	*Micbif*
Skimmia laureola (DC.) Seib. & Zucc. ex Walp.	*Skilau*
Dioscorea deltoidea Wall.	*Diodel*
Lespedeza juncea (L.f.) Pers.	*Lesjun*
Hedera helix L.	*Hedhel*
Polygonum biaristatum Aitch. & Hemsl.	*Polbia*
Rosa webbiana Wall ex Royle	*Malweb*
Malva neglecta L.	*Malneg*
Fumaria indica (Hausskn.) H.N.	*Fumind*
Polygonatum multiflorum L.	*Polmul*
Nepeta erecta Benth.	*Nepere*
Dryopteris stewartii More	*Dryste*
Jasminum officinale L.	*Jasoff*
Rubia manjith Roxb. ex Fleming	*Rubman*
Salvia officinalis L.	*Saloff*
Aconitum heterophyllum Wall	*Acohet*
Andropogon himalayensis Gand.	*Andhim*
Rumex dentatus L.	*Rumden*
Origanum vulgare L.	*Orivul*
Saussurea atkinsonii C.B.Clarke.	*Sauatk*
Hypericum perforatum L.	*Hypper*
Pistacia integerrima Stew. ex Brandis.	*Picint*
Medicago polymorpha L.	*Medpol*
Urtica dioca L.	*Urtdio*
Acorus calamus L.	*Acocal*
Calotropis procera (Aiton) W.T.Aiton	*Calpro*
Thymus linearis Benth.	*Thylin*
Otostegia limbata (Benth.) Boiss.	*Otolim*
Geranium wallichianum D.Don ex Sweet	*Gerwal*
Gymnosporia royleana Wall. ex Lawson in Hook.f.	*Gymroy*
Nasturtium officinale R. Br.	*Nasoff*
Artemisia maritima L.	*Artmar*
Oxalis corniculata L.	*Oxacor*
Pimpinella diversifolia DC.	*Pimdiv*
Desmodium elegans DC.	*Desele*
Vitis jacquemontii R. N. Parker	*Vitjac*
Portulaca oleracea L.	*Porole*
Mentha longifolia L.	*Menlon*
Onopordum acanthium L.	*Onoaca*

Aconitum violaceum Jacq. ex Stapf	*Acovio*
Corylus colurna L.	*Corcol*
Leonurus cardiaca L.	*Leocar*
Hedera nepalensis K.Koch	*Hednep*
Calendula officinalis L.	*Caloff*
Taraxacum officinale Weber.	*Taroff*
Senecio chrysanthemoides DC.	*Senchr*
Ranunculus muricatus L.	*Ranmur*
Cotoneaster microphylla Wall.ex.Lindley	*Cotmic*
Parrotiopsis jacquemontiana (Dcne.) Rehder	*Parjac*
Arisaema jacquemontii Blume.	*Arijac*
Sorbaria tomentosa (Linley) Rehder	*Sortom*
Geranium nepalense Sweet.	*Gernep*
Buxus wallichiana Baill.	*Buxwal*
Santolina incana Nana	*Saninc*
Capsella bursa-pastoris(L.) Medik.	*Capbur*
Chenopodium botrys L.	*Chebot*
Asparagus gracilis Royle	*Aspgra*
Trillium govanianum Wall. ex Royle	*Trigov*
Phytolacca acinosa Roxb.	*Phyaci*
Chenopodium album L.	*Chealb*

Appendix 2

Plant Species	**Symbol**
Abies pindrow Royle	*Abipin*
Acacia modesta Wall	*Acamod*
Alnus nitida (Spach.) Endl.	*Alnnit*
Alnus nitida (Spach.) Endl.	*Aesind*
Betula utilis D.Don	*Betuti*
Cedrella serrata Royle.	*Cedser*
Cedrus deodara (Roxb.ex Lamb.) G.Don	*Ceddeo*
Celtis caucasica L.	*Celcau*
Diospyrus lotus L.	*Diolot*
Euclyptus spp.	*Eucspp*
Ficus spp.	*Ficspp*
Juglans regia L.	*Jugreg*
Melia azedarach L.	*Melaze*

Morus spp.	*Morspp*
Olea ferruginea Royle	*Olefer*
Picea smithiana (Wall.) Boiss.	*Picsmi*
Pinus roxburghii Sargent.	*Pinrox*
Pinus wallichiana A. B. Jackson	*Pinwal*
Platanus orientalis L.	*Plaori*
Pyrus spp.	*Pyrspp*
Quercus baloot Griff.	*Quebal*
Quercus dilatata Lindley ex Royle.	*Quedil*
Quercus incana Roxb.	*Queinc*
Salix babylonica L.	*Salbab*
Salix tetrasperma Roxb.	*Saltet*
Taxus baccata L.	*Taxbac*

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