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INFLUENCE OF ENVIRONMENTAL VARIABLES ON THE DISTRIBUTION OF WOODY SPECIES IN MUSLIM GRAVEYARDS OF MALAKAND DIVISION, HINDUKUSH RANGE MOUNTAINS OF PAKISTAN

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Abstract

Muslim graveyards are believed to be the most protected microecosystems and were regarded the most ideal habitats for natural vegetation due to special cultural roles and religious privileges. In the foothills of Malakand division, located in the Hindukush range mountains, these microecosystems have been substantially disturbed by the recent army incursion but still offer an opportunity for studying comparatively less disturbed vegetation where vegetation-environment relationships have hardly been explored. Therefore, we investigated the effect of environmental variables on the composition and structure of woody vegetation, crucial to understand for the conservation of these graveyards. An investigation of the vegetation and its associated environmental variables in thirty different graveyards was performed by using 10 × 10 m^2 plots resulted to encounter 2592 trees (DBH ≤ 5 cm) of twenty different woody species belonging to 16 families in the entire landscape. The cluster analysis identified five major community types with density and basal area ranging from 150 to 1620 trees ha^{-1} and 20 to 2523 m^2ha^{-1} respectively. The analysis revealed that family Moraceae contributed maximum number of species followed by Rosaceae, Meliaceae and Fabaceae to the overall floristic composition. Canonical correspondence analysis (CCA) was used to assess the relative explanatory power of different physiographic and soil's physical and chemical properties for the vegetation structure and composition. Significant interactions with elevation, soil clay, silt, sand, phosphorus and potassium suggest that several factors explained the spatial pattern but effect of physiographic factors were comparatively higher than soil factors on the vegetation composition. Thus, we predict that elevation coupled with soil physical and chemical properties are more influential and could be considered in vegetation restoration and conservation in these graveyards. Our results suggest that both local and regional scale analyses are warranted to disentangle the vegetation-environment relationships, if the ultimate goal is to conserve these less disturbed, self-sustainable ecosystems.

Key words: Vegetation-environment relationship, Muslim graveyards, Plant community, Microecosystem, CCA-ordination, Spatial analysis.

Introduction

The aim of vegetation ecology is to realize the causes responsible for the distribution of plant communities (Barton, 1993; El-Bana & Al-Mathnani, 2009) that change gradually along environmental factors (McCune & Grace, 2002). However, species distribution and diversity reflects the effects of several gradients at a regional and landscape level (Eilu *et al*., 2004) of which climate, physiography and soil are considered to be the overriding factors responsible for distribution patterns (McAuliffe, 1994; Shaltout *et al.*, 1995; Ringrose *et al.*, 2003). Several authors have found that human induced and natural hazards are also amongst the well-known factors that highly affect the structure, composition and function of the forest ecosystems (Timilsina *et al.*, 2009). The likely importance of spatial factors, biotic interactions and environmental stochasticity must be counted additionally for consideration of interaction of plant communities with environmental factors (Song *et al.*, 2009).

Subtropical dry temperate forests of Hindukush range are an area with rich floristic diversity, because of the multiplicity in ecological extents (Stewart, 1982) and are considered as globally important biodiversity hotspots. The eastern Hindukush range vegetation reveals the principal pitch of declining annual rainfall from southeast to northwest with an understandable characteristic of elevation zonation in flora traversing more than 4,000 m a.s.l. (Nusser & Dickore, 2002). However, Hindukush range forests of Malakand division are unfortunately in crisis mainly due to natural and anthropogenic turbulences, including security risks (Khan *et al.*, 2013; Khan *et al.*, 2015). Agricultural intensification, over-growing population and urbanization has also resulted in significant degradation of natural habitats that lead to enormous decrease in the productive and protective forests in diverse elevational straps and sub-regions (Alamgir, 2004; Khan *et al.*, 2011). One best example is the vegetation of Muslim graveyards in Malakand division which have been cleared recently by army owing to the security risks during military operation against the terrorists, nevertheless represent refuges for different kinds of plants in the country (Stewart, 1982; Champion *et al.*, 1965) and even worldwide (Molnar *et al.*, 2017). Despite the considerable anthropogenic pressure, these graveyards still offer an opportunity for studying comparatively less disturbed vegetation than other habitats as less strongly affected landscape-altering human activities are observed in it due to special cultural roles and religious privileges (Loki *et al.*, 2015).

A review of literature reveals very few studies (i.e. Kreutz, 1998; Kreutz & Colak, 2009) around the world particularly in Muslim countries where phytosociology or any ecological aspect of the graveyards vegetation have been explored. More recently a comprehensive survey was conducted in 300 Turkish graveyards located in 30 provinces as Orchid habitats (Loki *et al.*, 2015) and reported 86 taxa which is almost half of the known Turkish orchid flora. Molnar *et al.* (2017) made intensive study on orchids and environmental variables in 166 Albanian graveyards and found that Muslim graveyards were significantly larger with comparatively less proportion of area being covered by graves than the Christian ones. They documented 29 taxa in 88 graveyards and reported that Muslim graveyards are rich in orchid taxa compared to others. The authors concluded that graveyards can be considered as significant refugia for orchids, and the long-term management influenced by the religious affiliation may have a significant impact on its natural values. Other studies have focused on the medicinal aspects of plants appeared in graveyard (e.g. Dafni, 2006; Rahman *et al.*, 2008; Hadi *et al.*, 2014). The available literature elucidates the situation, clarity to the investigation, since studies conducted on this aspect across the world is very meager and scatter.

Published data have shown very few attempts to study these graveyards merely for a phytosociological prospective (e.g. Niazi 1975; Chaghtai *et al.*, 1978; Chaghtai *et al.*, 1983; Ahmed *et al.*, 2009 and Ahmad *et al.*, 2010). These workers have summarized the floristics subdomain in different graveyards communities and no work has considered at these graveyards vegetation patterns beyond comparatively local scales to observe the relationship of environmental factors and vegetation using non-numerical techniques. This is probably because of a symbol of respect and significant dissimilarity in the parent materials of soils, as the decay of human bodies continuously adding nutrients to the soil in these microhabitats (Chaghtai *et al.*, 1978). Therefore, it was crucial to assess the influence of environmental variables on the vegetation distribution of these graveyards which are regarded ideal for the study of natural vegetation using advanced numerical methods. Consequently, a comprehensive study of the Muslim graveyards was conducted with the objectives 1) to investigate plant communities and 2) to explore the effect of environmental variables to detect the major controlling factors of species distribution. These results will be helpful to assess the conservation and management values of these microhabitats in Malakand division of northern Pakistan.

Material and Methods

Study site: This work was conducted in the subtropical dry temperate forest zone of Malakand division, Hindukush Range Mountains of Pakistan (Fig. 1). Major graveyards of the area were sampled which were of at least 1 to 2 hectares in area. The total area of Malakand division is 952 km^2, and possesses one of the largest broadleaved and coniferous forests in Pakistan. The elevation of the division ranges from 700 m and 7708 m with uneven terrain, undulating vales, medium to steep slopes hillocks, massive mountains, plains and many water tributaries joining major rivers are the characteristics features of the study area (Hazrat *et al.*, 2008; Khan *et al.*, 2013).

The study area was once primarily a landscape of large stretches shrub lands, woodland of broadleaved, deciduous, pine and coniferous tree species (Champion *et al.*, 1965). However, during the last 50 years, the primary vegetation has been damaged by long-term anthropogenic disturbance and climate change leading to chronic water and soil erosion (Ali *et al.*, 2013; Khan *et al.*, 2015). About 6000 vascular plants have been documented within the intact topographical territory of Pakistan dispersed in diverse climatic regions (Nasir & Ali, 1972; Ali & Qaiser, 2009). Of which more than 2500 species have been documented in northern areas including Malakand Division, representing rich floristic diversity of the sub-region in Sino-Japanese phyto-geographical constituency of the globe (Sher & Hussain, 2009; Rahman, 2012). Such a rich floristic composition is obviously due to climatic variability of the region predominantly interrelated to elevation gradient (Khan *et al.*, 2010). Climatic data of the Chitral, Droash, Swat and Dir meteorological stations show (PMD data 2011 to 2013) that June is the hottest month (max average temp is 34.65, mini 17.62°C), where as the coldest month is January (max is 9.2°C and mini –2.25°C).

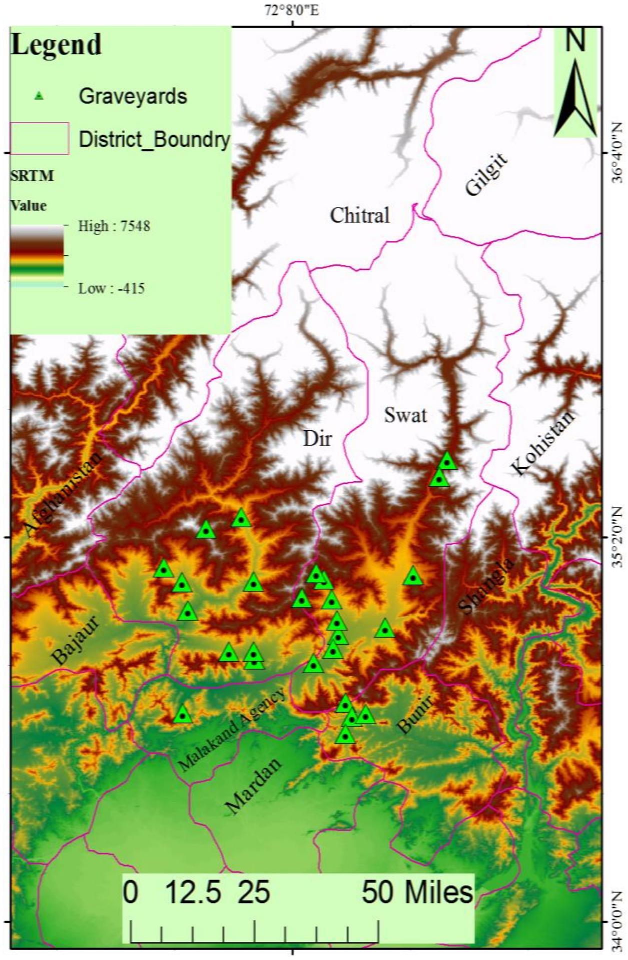

Fig. 1. Shuttle Radar Topography Mission (SRTM) of the study area showing the altitudinal variation. Map showing altitudinal topographical variations and sampling sites in the foot-hills of Malakand division, Hindukush range of Pakistan

The total precipitation for Malakand division shows substantial variation across the year (ranged from 410 to 1334.3 mm for the year 2011 to 2013) with the arid season from May to July averaging 5.13 mm from weak fronts, and rainy season occurring from August to October average 56.62 mm (Khan *et al.*, 2011; Khan *et al.*, 2015) possibly due to rain shadow mountains with occasional monsoon. The relative weak correlation of different climatic parameters (e.g. temperature; r = 0.7423, precipitation; r = 0. 7723, $p<0.01$) from the various meteorological stations located at various elevation in Malakand Division suggest climatic variability in the region. Snowfall generally starts from late November to mid of March, whereas, relative humidity remains moderate throughout the year (Shah *et al.*, 2010; Wahab, 2011).

Data collection: Twenty plots of 10 × 10 m^2 at thirty different sites (n= 30 × 20 =600) were randomly settled along a transect line that traversed through the center of each graveyard vegetation in the major districts of Malakand division. The sampled sites were at least 2 ha in area positioned both on hill slopes as well in natural vegetation of plain graveyards. Prior to vegetation sampling, geophysical and physiographic characteristics of the stands were recorded with the help of a handheld Global Positioning system (GPS) and clinometer.

At each sampling site, the first plot was randomly positioned in graveyard vegetation avoiding any anthropogenic and other impacts. Species in each plot were identified taxonomically along with vernacular names supplied by knowledgeable local inhabitants and voucher specimens were then verified by visits to the Herbarium in Post Graduate Jahanzeb College Swat and Botanical Garden University of Malakand. The plant species were subsequently assigned to its corresponding chorological group, sub-group and floristic element based on the geographical distribution and phylogenetic relations (Zohary, 1973; Takhtajan 1986). We also measured diameter at breast height 1.3 m (DBH) for all the woody stems ≥5 cm DBH excluding lianas. As some tree species, do not produce clear boles and arise with multi-stems leading to the bias in estimation of diameter. To avoid such confusions for multi-stemmed trees, diameter approximation was considered following Russel & Fowler, (1999) and Ryniker *et al.* (2006). Height of trees was also estimated by a scale marked wooden stick while a tape was used to measure fallen and cut trees.

Soil analysis: Soil samples were collected at each plot from the upper 30 cm soil crust from individual forest stand at three sub-zones, thoroughly mixed, air dried and analyzed in the soil laboratory at Takhtaban Agriculture Research Centre Swat. Soil pH was calculated in the field by a dynamic pH meter (model P9565-IAE) and proportion of coarse particles (gravel, silt, clay and sand) was determined by sieve analysis (Anon 1961; Buol *et al.*, 1980) and hydrometer procedure (Bhatnagar, 1965; Bouyoucos, 1962). Total nitrogen was determined after Bremner and Mulvaney, (1982) and soil organic matter following the method of Jackson, (1958). Available soil phosphorus and exchangeable potassium (K^+) were estimated using Flame Photometer following the method described by Peech & English, (1944) and Pratt, (1965).

Data analysis: Importance values of each woody tree species in individual forest stand were calculated using relative values of frequency, density and basal area (Greig-Smith, 1983). This synthetic index is recommended by several workers (Kent and Coker, 1992; Baruch, 2005) as it reflects the degree of dominance, abundance and help in the conservation and management of a species (Song *et al.*, 2009). To empirically measure the biodiversity, Alpha diversity in different stands was estimated by species richness indices (Margalef's (D_{Mg}), Simpson's (SI), Shannon-Wiener (Sh_{WI}) and Menhinick) in order to obtained a comparative quantitative estimate for compositional variability among different stands (Pielou, 1969). Such estimates are simple, easy to calculate and of great interest to ecologists and policy makers for various ecological settings (Purvis & Hector, 2000). Density and basal area were also calculated for individual sites ranged from high density of small diameter stems of one predominant species to stand of extremely low density of larger diameter stems of many species. Since, a visible and ecologically interpretable pattern emerged (see results), we did not try ordinating transformation of density or basal area variables, as sometime recommended (e.g. Ahmed, 1984; Knox & Peet, 1989). We obtained descriptive statistics for all the topographic and soil properties and were analyzed using Kruskal-Wallis H-test (an alternative of one-way ANOVA) for significant testing and comparison among different community types.

Vegetation types were identified by Ward's Agglomerative cluster analysis and the floristic patterns were described by Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA). The techniques are recommended for objective classification of heterogeneous data sets and exploratory analysis where specific hypothesis of factors or patterning of experimental sampling units is unknown (Orloci, 1975; Hill & Gauch, 1980; McCune and Grace, 2002). Both of the ordination techniques were conducted using PC-ORD version 5.10 (McCune & Grace, 2002) and XL-statistic software for graphics. DCA was first run to check outliers using the importance values of tree species in all forest stands and the modified data were subjected to CCA to attribute in the patterns in DCA with underlying environmental variables. James & McCulloch (1990) have reported that CCA only shows correspondence among the species distribution and environmental variables and do not necessarily reflects biological causation. The Monte Carlo permutation test (p = 0.05) was also performed to test the relationship between matrices and statistically evaluate whether the CCA is extracting stronger axes than expected by chance. For interset relationship of different environmental variables we used correlation coefficients and significant relationships were highlighted.

Results

Floristic and chorological affinities: The study recorded twenty species belonging to 12 genera of 15 families in tree stratum (≤ 10 DBH) and was used for analysis. Of these families Moraceae was the largest family (3 species), followed by Meliaceae, Rosaceae and Fabaceae (2 species each). The remaining 11 families were represented by one species (Table 1). All these families constituted about 45% of the recorded woody flora and represent most of the floristic structure in graveyards of Malakand division. The largest genus was *Ficus* with 6 species of which four species were ubiquitous (have a wide range of distribution). The chorological affinities of the surveyed flora revealed that 30% species were mono-regional, 5% were exotic typical of Sino-Japanese region (Table 2). About 50% of the recorded species were native of Iranian-Touraian region, 60% were bi-regional and 15% were pluri-regional extending their distribution all over the Indian and Mediterranean regions. Overall, Sino-Japanese region, constitutes 55% of recorded flora, thus it forms the major component of the floristic composition of this study.

Table 1. Tree families, number of genera and species recorded in five different community types.

Family	No. of genera	No. of species	Family	No. of genera	No. of species
Moraceae	3	3	Pinaceae	1	1
Fabaceae	2	2	Platanaceae	1	1
Rosaceae	2	2	Fagaceae	1	1
Meliaceae	2	2	Salicaceae	1	1
Lythraceae	1	1	Sapotaceae	1	1
Juglandaceae	1	1	Simarobacea	1	1
Cannabaceae	1	1	Tiliacea	1	1
Oleacea	1	1			

Table 2. Summary of the chronology of woody plant species in the study area.

Tree species	Regions		Regions	Percentage
Acacia modesta	SU, SS	Bi-regional	SU	10%
Alianthus altissima	C. Asia	Bi-regional	SS	5%
Broussonetia papyrifera	E.Asia, C. Asia, Itly	Pluri-regional	C. Asia	10%
Celtus europia	PLU	Uni-regional	E. Asia	10%
Dilbergia sisso	IG Basin	Uni-regional	Italy	5%
Ficus palmata	IT, M, ES	Pluri-regional	Greece	5%
Monotheca buxifolia	Trop	Uni-regional	PLU	5%
Melia azadrach	M	Uni-regional	IG Basin	5%
Morus alba	IT, Cos	Bi-regional	IT	50%
Olea ferruginea	M, IT	Bi-regional	M	15%
Quercus ilex	ES, ES	Bi-regional	ES	50%
Prunus armenica	IT,ES	Bi-regional	Trop	5%
Platanus orientilis	IT,SI	Bi-regional	Cos	5%
Punica granatum	SU, E.Asia	Bi-regional	SI	5%
Populus nigra	IT,ES	Bi-regional	SI	5%
Juglans regia	IT,ES	Bi-regional		
Pyrus communis	IT,ES	Bi-regional	Bi-regional	60%
Grewia asaitica	IT,ES	Bi-regional		
Cedrella serreta	IT	Uni-regional		
Pinus roxburghii	ES	Uni-regional		

SU= Sudano-Zambezian, SS= Saharo Sindian, C. Asia= Central Asia, E. Asia= East Asia, Itly= Italy, PLU= Pluri regional, IG Basin= Indo-Gangetic basins, IT= Irano-turanian , M= Mediterranean, ES= Euro Siberian, Trop= Tropical, Cos= Cosmopolitan , ES = Euro-Sibirian, SI= Siberian

Description of the community types: The twenty-woody species in 30 forest stands were satisfactorily clustered into five communities (Group I-V; Fig. 2) at 75% of information in the abundance of species retained. The resulted community types were openly detached from each other in the NMS ordination configuration (results not shown). Phytosociological attributes, absolute values and environmental features of these vegetation types were summarized in Tables 3, 4 and 5 respectively which showed high variability for different parameters. Group-I (*O. ferruginea* and *M. azedarach*) and Group-IV (*O. ferruginea* and *A. modesta*) were located at low elevations facing toward north aspect with low slope angle, pH, high organic matter, potassium and sand contents. These forest types were the most diverse with high woody species richness, density ha^{-1} and basal area m^{2}ha^{-1} (Table 4). The understory vegetation comprised of huge native shrubs i.e. *Dodonea viscosa*, *Artemisia maritima*, *Nerium olender*, *Daphne mucronata* and *Gymnosporia heterophylla*.

Group-II (*O. ferruginea* and *C. europia*) and Group-III (*O. ferruginea* and *M. alba*) occurred at medium elevations on west aspects with high silt, organic matter, nitrogen (%) and medium phosphorus and potassium contents. Among these populations, Group-II had high stem density and basal area but Group-III shared <3% of the total stem density and basal area. Both communities contributed six different species with sparse understory vegetation mostly composed of herbaceous species such as *Micromeria biflora*, *Chenopodium album* and *Teucrium stocksianum*. Group-V (*O. ferruginea* and *Q. incana*) distributed at high elevation facing toward north with high clay, silt particles, low pH, lime (%), nitrogen, phosphorus and available potassium content. This type is species poor community and contributed 15.86% stem density and 18.15% basal area of the overall communities (Table 4). Shrub and herb layers were represented by few thorny species such as *Otostegia limbata*, *Acacia* seedlings and *Zanthozylum armatum*.

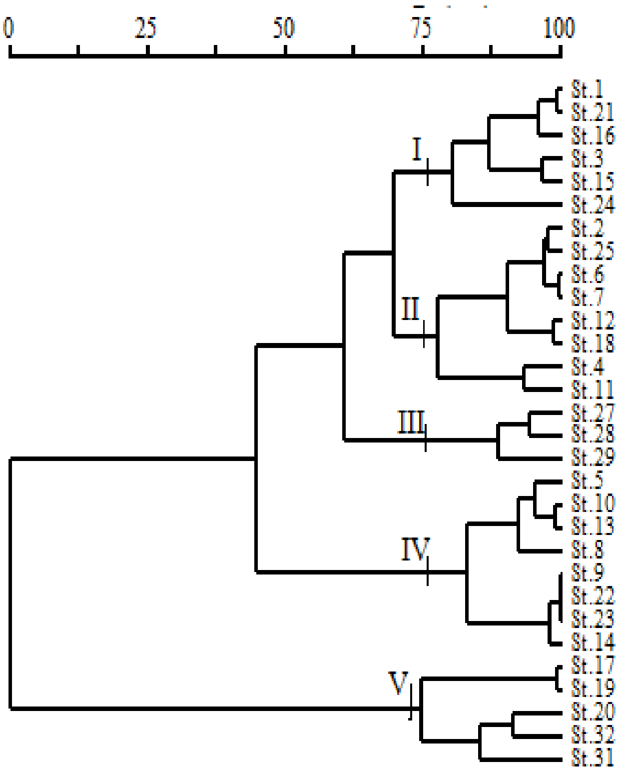

Fig. 2. Cluster analysis of the 30 sampling sites and 20 tree species showing five clusters(communities) with 75% (7.91% chaining) information in the abundance of species retained.

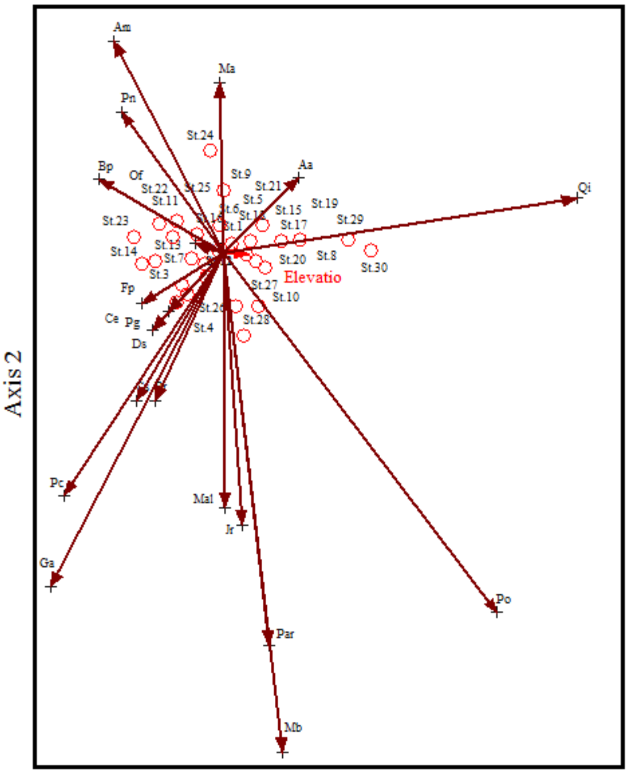

Fig. 3. Ordination diagram (CCA-biplot) showing the result of sites-environment of 30 graveyards vegetation. Species and environmental variables used in the analysis are abbreviated, and full names are shown in Tables 2 and 3 respectively.

Table 3. Descriptive statistic of the environmental variables in the five tree communities of graveyards. Kruskal-Wallis test was performed on the environmental characteristics for statistical significance.

	I *O. ferruginea* *M. azadarch*	II *O. ferruginea* *C. europea*	III *O. ferruginea* *M. alba*	IV *O. ferruginea* *A. modesta*	V *O. ferruginea* *Q. ilex*	H-statistics	*P*-values
Elevation	959 (103)	1065(355)	1039(77)	865(193)	1258(236)	8.74	**0.068**
Slope (°)	8(6.4)	8.87(6.91)	10.6(1.66)	8.12(9.0)	10.4(3.20	5.56	**0.234**
Aspect	1.66(0.81)	2.37(1.30)	2(1)	1.5(0.75)	1.8(1.09)	2.626	0.622
Clay (%)	14(2.63)	14.5(2.32)	14.5(4.1)	14.6(2.4)	14.9(3.9)	0.232	0.994
Silt (%)	32(13.0)	48.9 (11.7)	47.8(2.3)	42.8(8.9)	45(9.91)	6.757	**0.149**
Sand (%)	53(15.6)	38.9(11.8)	37.6(6)	43.2(9.2)	39.7(12)	5.81	**0.214**
pH (1:5)	7.6(0.28)	7.5(0.33)	7.7(0.05)	7.55(0.25)	7.6(0.13)	2.927	0.57
O. matter (%)	1.95(1.91)	1.98(1.7)	2.5(3.22)	2.0(1.2)	1.45(0.8)	1.77	0.778
Lime (%)	10(1.53)	10(3.62)	16.3(5.39)	13.4(5.5)	10.4(2.8)	5.835	**0.212**
Nitrogen	0.10(0.09)	0.10(0.08)	0.12(0.16)	0.10(0.06)	0.07(0.04)	1.123	0.891
P (mg/kg)	8.49(1.74)	11.6(10.7)	6.33(1.34)	7.39(1.70)	8.21(2.6)	3.838	**0.428**
K (mg/kg)	163(148)	134(60.6)	121(27.5)	107(65.1)	98.8(39.1)	2.131	0.712

Table 4. Tree species diversity for the five different community types obtained from cluster analysis.

F. types	D/ha	B.A (m^2/ha)	SR	SI	Sh_{WI}	Me	D_{Mg}	Eq
1	1620	2352	7	0.92	1.6	0.83	1.119	0.59
2	2615	2178	6	0.86	1.62	0.53	1.015	0.65
3	150	20	6	0.98	1.2	0.56	0.696	0.49
4	1347	2209	5	1.6	0.55	0.39	0.545	0.33
5	1155	1499	4	0.87	1.3	0.44	0.656	0.83
∑	**7288**	**8258**	**20**					

F. types, Forest types; SR, Species richness. Si, Simpson's index. Sh_{WI}, Shannon-wiener index. Menhinick index. Mg, Margalef's index. Eq, Equitability

Table 5. Summary of the taxa for all the woody tree species (≤ 10cm DBH) in the five different community types.

Forest types	**1**	**2**	**3**	**4**	**5**
Number of trees	463	965	203	583	378
Number of families	12	9	8	7	8
Number of Genera	16	12	8	7	8
Number of species	16	12	9	9	9

Factors influencing species distribution patterns: The effect of various environmental variables on the patterns of woody species distribution was exposed by CA bi-plot (Fig. 3). The eigen-values of CCA and DCA, total inertia and cumulative percentage variance of species data (CCA) are given in Table 6 and canonical correlation coefficients of the site scores with environmental variables are shown in Table 7. The correlation among these variables displayed virtually total impendence, that usually simplifies interpretation of the present results. A stable solution was obtained instantly with a tolerance level of 0.100000E-12 (= 10^{-13}) after 23, 24, and 16 iterations for the first three canonical axes, respectively. The F ratios of the unrestricted Monte Carlo test permutation showed strong relationship between the matrices, i.e. eigenvalues (p =0.0941) and species-environment (p = 0.2733) correlation, indicating that observed patterns did not arise by chance. Table 6 showed that first three axes explained 32% of the variability in species data, of which 17.3% was accounted for the first axis. The results also showed an overall significant correlation (0.827, P = 0.02) between species and environmental variables in the first CCA axis. CCA ordination generally show a complex pattern of species composition along different environmental variables of which elevation is the only among physiographic and soil factors which produced highest positive correlation (r = 0.838) with canonical axis 1. The results of canonical coefficients suggested that soil physical properties i.e. clay, silt and sand were the most prominent factors correlated with axis 2 (Table 7), whereas, phosphorus (r = -0.354) and potassium (r = 0.390) additionally exhibited some negative relationships in increasing order with axis 1.

The biplot species data shows the species that has greater loading on the axes, are *G. asaitica*, *P. communis*, *J. regia*, and *M. alba* which occupied the negative end of Axis 1, whereas, *M. busxifolia and P. armenica* occupied the lower and *Q. ilex* and *Platanus orientilis* occupied the upper and lower positive ends, respectively (Fig. 3). This suggest that species along positive axis is extending their population while species towards the negative axis are shrinking along a similar underlying gradient. In addition, several species like *F. palmata*, *P. granatum*, *C. europia*, *A. altissima B. papyrifera*, *D. sisso*, *M. azadrach*, *A. modesta* and *P. nigra* formed clusters with *O. ferruginea* which was a dominant species of these microhabitats. These species grouped in the upper middle of the ordination continuum (CCA-biplot) which shows that these species are strong companions under the same governance of environmental variables.

Table 6. Showing eigen-values of the three axes for CCA of 30 plots and the value of species environmental and cumulative variance relationship with the CCA axes.

	Axis 1	**Axis 2**	**Axis 3**	**p-value**
Eigenvalue (CCA) (total inertia 1.523)	0.263	0.134	0.087	0.0941
Variance in species data % of variance explained	17.3	8.8	5.7	
Cumulative % explained	17.3	26.1	31.8	
Pearson Correlation, Spp-Envt*	0.827	0.760	0.765	
Kendall (Rank) Corr., Spp-Envt	0.614	0.508	0.379	

Table 7. Canonical coefficients between the site-scores and twelve environmental variables obtained from CCA.

Variables	**Axis 1**	**Axis 2**	**Axis 3**
Elevation	0.838**	-0.050	0.061
Slope	0.222	-0.071	0.125
Aspect	-0.122	-0.178	0.054
Clay	-0.434*	0.016	0.378*
Silt (%)	-1.396	-0.687*	1.656
Sand (%)	-1.162	-0.466*	1.729
pH (1:5)	-0.254	-0.181	-0.002
Organic matter (%)	-0.003	-0.016	-0.089
Lime (%)	-0.074	-0.362*	-0.087
Nitrogen (%)	0.015	0.180	0.098
Phosphorus (mg/kg)	-0.354*	0.152	-0.248
Potassium (mg/kg)	-0.390*	-0.329*	-0.094

Table 8. Inter correlation among different physiographic, and soil physical and chemical parameters.

	Ele	Slo	Asp	Clay	Silt	Sand	pH	% o. matter	% lime	%N	P	K
Elevation	1											
Slope	-0.105	1										
Aspect	-0.285	0.022	1									
Clay (%)	0.006	-0.126	-0.197	1								
Silt (%)	0.572***	-0.312	-0.065	0.035	1							
Sand (%)	-0.485	0.340*	0.093	-0.347	-0.928	1						
pH (1:5)	-0.061	0.037	-0.175	0.403*	-0.087	-0.155	1					
% O. matter	-0.207	-0.107	0.291	0.273	0.119	-0.203	-0.212	1				
% lime	-0.328	-0.024	0.002	0.378**	0.006	-0.158	0.143	0.550***	1			
% N	-0.137	-0.265	0.169	0.325	0.190	-0.290	-0.221	0.899***	0.508***	1		
P	0.5670***	0.009	-0.172	-0.314	0.316	-0.074	-0.495	-0.144	-0.314	-0.146	1	
K	0.1143	0.369*	-0.273	-0.341	-0.322	0.448**	-0.258	-0.159	-0.324	-0.113	0.260	1

Inter correlations among the explanatory variables: The inter correlation among different physiographic and soil variables is shown in Table 8. The soil silt (r= 0.572) and phosphorus contents (r =0.567) were positively correlated while lime and sand (-0.485) showed some clear negative relationships with elevation. The slope showed a negative correlation with % N (r =-0.265) and positive with sand (r = 0.340) and soil available potassium (r =0.359) contents. The clay content showed a positive correlation with the soil pH (r=0.403) and nitrogen (r =0.325) and a significant negative correlation with Potassium (r= -0.341) of the soil. Among the textural properties of soil, silt exhibited a strong negative relationship with sand (r =-0.928) and comparatively weak relationship with potassium content (r =0.322). The sand content also showed a significant positive correlation with potassium (r =0.448) and % nitrogen with lime (Table 8). In addition, available phosphorus and potassium exhibited a negative relationship with lime (%) in increasing order.

Discussion

Among the nine ecological zones of Pakistan, Hindukush range is considered as a hub to biodiversity with numerous plant species, most of which are of high economic and medicinal importance (Sher & Hussain, 2009; Ali *et al.*, 2013). To this biodiversity hub, Muslim graveyards which are comparatively less disturbed microhabitats have significant contribution due to special cultural roles and religious privileges (Chaghtai *et al.*, 1978). The floristic composition indicated that twenty woody species belonging to 12 genera and 15 families, of which Moraceae was the largest family followed by Meliaceae and Rosaceae. The chorological affinities of the recorded flora revealed that these graveyards supported plant species with a wide distribution and representative of several phytogeographical regions of the world. Using the quantitative classification method (Ward's method) and ordination technique (CCA), the analyses displayed in this research clearly describe the distribution pattern of woody species composition in these microhabitats. According to Molnar *et al.* (2017), vegetation and floristic composition of Muslim graveyards are more natural than those of the surrounding areas, the phenomenon reported here for woody tree species is presumably not unique. Cluster analysis, identified five community types, each of which hold distinct ecological niches, representing a unique arrangement of plant species and its distribution reflects the comprehensive influence of environmental variables.

According to the present classification of vegetation in these graveyards, the five communities are *O. ferruginea* and *M. azedarach* (Group I), *O. ferruginea* and *C. europia* (Group II), *O. ferruginea* and *M. alba* (Group III), *O. ferruginea* and *A. modesta* (Group IV) *and O. ferruginea* and *Q. baloot* (Group V) respectively. The results indicated that community type I and IV appeared on low elevation (865 to 959 m a.s.l) where habitats were warm and humid. The other community types occurred between an elevation ranged of 1039 m to 1258 m where environmental conditions were comparatively cooler. In the above elevational range, several broadleaved and deciduous tree species were present but *O. ferruginea* occurred in all the microhabitats as leading species with varied densities and basal area, reflecting the broad distribution of this species. These results are in conformity to Molnar *et al.* (2017), stated that several plants regularly appeared particularly with stable populations of *O. ferruginea*, threatened by human activities in the Muslim graveyards (Ahmed *et al.*, 2009). Minor associates like *F. palmata*, *C. europia* and *M. alba* also appeared with *O. ferruginea* but none of them occurred as co-dominant species except *C. europia* in community type 2 (Group II). Several species listed in Table 2 show their narrow distribution because of their occurrence and minor contribution in all the sample plots and communities. The frequent distribution of some economically important species like *P. granatum* and *M. buxifolia* are reported with *O. ferruginea* from the upper elevational zones of the study area (Khan *et al.,* 2011). Few species (i.e. *J. regia*, *P. communis*, P. *armeniaca* and *P. roxburghii*) reported in this study are generally cultivated in graveyards by the local inhabitants for edible fruits and timber for construction purposes. With regard to the physiographic variations, vegetation in these graveyards were on gentle (0-15°) slope and facing towards north and west directions. It has been reported that water conditions (precipitation) on northern aspect are better than southern aspect which leads to the formation of broad-leaved evergreen and deciduous broad-leaved forests as also reported in the present study.

This view is also supported by Siddiqui *et al.* (2009) and Khan *et al.* (2013) who argued that northern aspects are more cooler and receive sufficient precipitation than others aspects in northern Pakistan. It was also observed that *M. buxifolia* and *P. granatum* which yield wild edible fruits in these microhabitats were present on northwest aspect might be due the light demand for fruit ripening. Several authors have advocated that the importance and effect of aspects on the distribution of different plant species and forest types across the globe (e.g. Jin *et al.*, 2008; Khan *et al.*, 2013).

Results have shown that several exotic species like *A. altissima*, *M. azedarach*, *C. serreta* and *B. papyrifera* are co-occurring with the dominant species and naturalized in these graveyards. Although exotic species have increasingly significant management problems and their removal may have unforeseen negative consequences (Antonio & Meyerson, 2002) or their use in restoration is desirable. The adverse effects of non-native species could bring long-term changes in the ecosystem processes (Vellend *et al.,* 2007; Murrell *et al.,* 2011), promoting evolutionary diversification and transformed opportunities for native species (Ramkrishanan & Vitousek, 1989). Therefore, its removal is recommended from the natural vegetation due to its expanding nature into natural habitats and thereby disrupting native plant communities (Wilcove *et al.,* 1998). On the other hand, native plants are well equipped to live within the local climate, soil types and animals forming a complex network of relationships, protect biodiversity and thus considered foundation of the natural ecosystem. In such a situation, the understanding of distribution and composition of plant communities and governing factors responsible for its pattern is indispensable as it is the main goal of plant ecology (Barton, 1993). Gradual changes in plant communities are easily observable along the environmental gradients (El-Bana & Al-Mathnani, 2009), therefore, understanding of plant species distribution in space with dependable factors is required for a particular area like graveyards which are exemplary structures (Barrett & Barrett, 2001) and considered as highly untouched protected places (Champion *et al.,* 1965). In the current study, we carried out the influence of physiographic and soil physical and chemical properties on the distribution of vegetation in Muslim graveyards using CCA and found that several environmental factors are associated with plant composition in these graveyard communities. The results of CCA indicate that elevation (r =0.838) is the strong influential variables than other factors, because change in elevational gradient lead to change in temperature and humidity gradient (Xianping *et al.,* 2006). Several authors have discussed the prominent role of elevation in vegetation development and distribution in mountains (e.g. Fisher and Fuel, 2004; Kabrick *et al.,* 2004; Mahdavi *et al.,* 2013; Khan *et al.,* 2013), and therefore, it is significant in vegetation restoration in such microhabitats.

The results of canonical coefficients also suggest that soil textural properties i.e. clay, silt and sand have significantly negative correlations with ecological groups of the species (Table 6). Our findings are supported by several studies (e.g. Badano *et al.,* 2005; Small and McCarthy, 2005; Mataji *et al.,* 2009), that soil texture also greatly influences the formation of plant communities. Additionally, potassium is important in defining the ecological groups and species richness in the present study as it plays an important role in regulating photosynthesis, carbohydrate transport, protein synthesis, and other physiological processes (Adel *et al.,* 2014). The availability of potassium also makes easy the transformation of water and nutrients and increase fertility of the soil. A more detail about the role of potassium in the distribution of plant species is described by Enright *et al.* (2005) and Zare Chahoki *et al.* (2007) in their studies. The use of natural vegetation as an indicator for site quality provides good results, due to the close relationship it has with abiotic site characteristics such as phosphorus in this study which is one of the governing soil factor for ecological groups. This may be due to the fact that phosphorus plays a fundamental role in plant nutrition, and its concentration and availability determine soil fertility and site productivity as it required in relatively large amount by the plants. Several workers have reported the direct relationships between the distribution of vegetation and phosphorus in their studies (e.g. Biggelow & Canham, 2002; Amorin & Batalha, 2007).

In conclusion, five different woody tree communities were identified and altitude coupled soil textural and physiochemical properties were found to be remarkably correlated with vegetation distribution pattern and must be considered while designing the management strategies. This study might provide better understanding of the mechanisms driving vegetation distribution in other surrounding of high mountain ranges. However, we recommend further study at both local and regional scales to disentangle the vegetation-environment relationships, and other biotic and abiotic factors must be considered for better understanding in these less disturbed microhabitats. We further recommend that local inhabitants must be educated through campaigns for the sustainable use of these fragile ecosystems. For this purpose, the basic needs and traditional rights of the local communities over the use of forest resources should be recognized which would be of course a positive attitude toward forest protection and development.

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