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Short Communication: Floristic composition and relationships between plant species abundance and soil properties in common hazel (*Corylus avellana*) mountainous forest of northern Iran

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Abstract. *Pourrahmati G, Mataji A, Pourbabaei H, Salehi A. 2018. Short Communication: Floristic composition and relationships between plant species abundance and soil properties in common hazel (Corylus avellana) mountainous forest of northern Iran. Biodiversitas 19: 1835-1841.* Mountainous forests are valuable terrestrial ecosystems because of their useful services for the human being. Here, we explored the floristic composition and the relationships between plant species abundance distribution and soil physical and chemical properties in common hazel (*Corylus avellana* L.) in the mountainous forest of northern Iran. Within the forest stand, 30 quadrats (20 m × 20 m and 1 m × 1 m for woody and herbaceous species, respectively) were selectively sampled along an altitudinal range from 1300 m to 1800 m a.s.l. to assess plant species composition and abundance, and soil samples were taken to perform chemical and physical analyses. The results showed that a total of 43 herbaceous and 15 woody species belonging to 23 and 8 families were identified. The abundance of herbaceous species was significantly correlated with soil properties (pH and total N). Furthermore, the abundance of woody species had a non-significant correlation with soil properties.

Keywords: CCA, *Corylus avellana*, distribution, mountainous forests, soil physical and chemical properties, species abundance

INTRODUCTION

Mountainous areas have been introduced as the prominent ecosystems since the Earth Summit in Rio de Janeiro in 1992. The services of mountainous forests, including provisioning, regulating, and cultural, are very vital for the human being (Price et al. 2011; Smith et al. 2015). The natural geographical distribution of the common hazel covers a vast area in the world, including Albania, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France (Corsica, France (mainland)), Georgia, Germany, Greece (Greece (mainland)), Hungary, Iran, Italy (Italy (mainland), Sardegna, Sicilia), Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Moldova, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation (Central European Russia, Chechnya, Dagestan, East European Russia, European Russia, Ingushetiya, Kabardino-Balkariya, Kaliningrad, Karachaevo-Cherkessiya, Krasnodar, North European Russia, Northwest European Russia, Severo-Osetiya, South European Russia, Stavropol), Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey (Turkey-in-Asia), Ukraine (Krym, Ukraine (main part)), United Kingdom (Great Britain, Northern Ireland) (Thompson et al. 1996). Naturally, common hazel grows in habitats with sandy soil and little nutrient elements in some mountainous areas in the north of Iran (Pourbabaei and Adel 2015).

The plant species are known as a primary component of ecosystem functioning, which are affected by the environmental factors (Montoya and Raffaelli 2010). According to the tolerance theory, each plant species is able to survive and reproduce successfully only within a definite range of environmental conditions (Good 1931). There is an interrelationship between plants and soil (Kirkpatrick et al. 2014; Srinivasan et al. 2015), so that, the vegetation growth correlates with some soil properties and vegetation also affects the soil properties (Johnson et al. 2014; Lee et al. 2014). Soil controls the hydrological, erosional, biological, and geochemical cycles in an ecosystem (Keesstra et al. 2012; Brevik et al. 2015; Smith et al. 2015) thereby affecting the plant species richness and composition (Rankin et al. 2007; Silva et al. 2013; Keymer and Lankau 2017). In mountainous areas, soil properties (i.e., physical and chemical features) along with topography can play an important role to develop plant communities (Miyamoto et al. 2003; Ravanbakhsh and Moshki 2016). According to the previous studies, the soil properties have been introduced as effective factors on variations in species abundance (Marcuzzo et al. 2013; Qian et al. 2014; Toure et al. 2015; An et al. 2015; Noumi 2015; Ghaderi et al. 2016). Vegetation is one of the most important factors affecting the stability of ecosystems (Ghaderi et al. 2016). Therefore, understanding the factors that govern patterns of plant species distribution and abundance is a mandatory requirement to control the establishment and distribution of plant communities in the mountainous areas of Iran.

In the mountainous ecosystems of northern Iran, the main soil challenges which impose particular constraints to plant establishment include the rocky substrates, soil scarcity, low water content, and low levels of nutrients. Hazel forests are unique and rare ecosystems in northern Iran and highly valuable because of their major contribution to the improvement of livelihoods and welfare of rural communities, protective function against natural hazards and conservation of many endemic and rare plant species. The most studies related to plant and soil relationships focused on tropical rainforests (Peña-Claros et al. 2011); there is less data base about temperate mountainous forests. As far as we know, there is no studies have paid attention to floristic composition and plant and soil relationships in the common hazel forest of Talesh in northern Iran. This study aimed to identify the floristic composition and investigate the relationships between plant species abundance and soil properties to address the following main question: Is there any relationships between the herbaceous and woody species abundance and soil physical and chemical properties?

MATERIALS AND METHODS

Study area

We conducted our study in the common hazel forest which is located on the northern slopes of the Alborz Mountains overlooking the Caspian Sea. The forest stand is located on the mountainous regions of Talesh (latitude: 37˚53′16″ N, longitude: 48˚39′28″ E) along an altitudinal gradient from 1300 m to 1800 m asl. (Figure 1). In this region, mean annual precipitation, temperature, and relative humidity were about 1300 mm, 13.19˚C, and 55%, respectively, and also soil pH was moderately acidic to neutral, soil texture was sandy loam, soil colour was dark brown (7.5YR4/2), and maximum soil depth was 60 cm.

Figure 1. The geographical location of study area in the mountainous areas of Talesh, Guilan, northern Iran

Data collection

Sampling of understory vegetation

We took a total of 30 sample plots (20 m × 20 m) selectively in the forest stand along an altitudinal range from 1300 m to 1800 m a.s.l. (Pourbabaei et al. 2012; Zhang et al. 2016). The forest stand was divided into five zones based on 100 m interval in the altitudinal gradient. The woody species with diameter at breast height (≥ 10 cm) in the plots were measured and the species was identified. Furthermore, individual shrubs and saplings (< 10 cm) were enumerated within the plots (Ihlen et al. 2001; Poorbabaei and Poorrahmati 2009). In order to survey the herbaceous layer, the sampling plot area (1 m × 1 m) was obtained according to the method of species/area curve (Cencini et al. 2012). The coverage percent and type of each herbaceous species was estimated using Van der Maarel criterion (Acosta et al. 2007).

Soil sampling and analysis

After litter removal from the mineral soil, we collected three soil samples (12.8 cm diameter, 0-20 cm depth) at three locations near the plot center using a soil auger for assessment of the soil chemical and physical properties. Then samples corresponding to each sampling plot were mixed to create a single sample (Vockenhuber et al. 2011). The soil samples were air-dried and sieved to pass a 2 mm sieve to remove the rocks, gravel and debris. The soil samples were analyzed for organic carbon (OC), electrical conductivity (EC), saturation moisture percentage (SP), texture, pH, total N, potassium (K^+), phosphorus (P^+), bulk density (BD), particle density (PD). The soil analyses were conducted in the Soil Testing Laboratory of Natural Recourses Faculty at University of Guilan. The percentage of organic carbon (OC) was determined using the Walkley and Black method (Lo et al. 2011), total N using the Kjeldahl procedure (Flowers and Bremner 1991), phosphorus (P) test was based on extraction with ammonium lactate (AL) at acidic pH (Olsen and Sommers 1982), available K was analyzed using a flame atomic absorption spectrophotometer (Cox et al. 1993), electrical conductivity (EC) was determined using the sodium saturation ratio (Van Reeuwijk 1992), pH was determined in a 1:5 soil water ratio suspensions using a digital pH-meter (Model 691, Metrohm AG Herisau Switzerland) (Thomas 1996), bulk density, particle density, water content, and total porosity were determined by oven-drying method, and the soil texture was determined by the hydrometer method (Bouyoucos 1962).

Data analysis

The CCA method was performed using a PC-Ord software version 5 (McCune et al. 2002) to study the plant abundance and soil relationship (Ter Braak 1986). The significance of axes was tested using the Monte Carlo permutation test (Ter Braak and Šmilauer 2002). The significance of eigenvalues of first canonical axis was tested using the Monte Carlo permutation test. The inter-set correlations from the ordination analysis were evaluated to assess the importance of various soil properties, including organic carbon (OC), electrical conductivity (EC), saturation moisture percentage (SP), texture, pH, total N, potassium (K^+), phosphorus (P^+), bulk density (BD), and particle density (PD) (Gazer 2011).

RESULTS AND DISCUSSION

Species composition

The results indicated that a total of 43 herbaceous and 15 woody species belonging to 23 and 8 families were found in the forest stand. The most species-rich families were the Asteraceae, Fabaceae, and Rosaceae, with 4, 3, and 11 genera and 5, 7, and 11 species, respectively (Tables 1 and 2).

Plant and soil relationship

Herbaceous species abundance and soil relationship

To analyze the herbaceous species abundance distribution and soil relationship, the CCA method was performed. The cumulative percentage variances for the axes of CCA (and their eigenvalues) are: 13.6 (0.26), 23.0 (0.18), and 29.4 (0.12) for axes 1, 2, and 3, respectively (Table 3). The correlation calculated for the first three axes of CCA includes: 0.94, 0.87, and 0.83. The Monte Carlo permutation test showed that the relationship was significant (Table 4; $p = 0.03$). Furthermore the effects of pH and total N on species abundance distribution were significant (Figure 2; $P < 0.05$).

Woody species abundance and soil relationship

The CCA method was performed to analyze the woody species abundance distribution and soil relationship. The cumulative percentage variances for axes of CCA (and their eigenvalues) are: 16.7 (0.05), 25.1 (0.02), and 29.8 (0.01) for axes 1, 2, and 3, respectively (Table 5). The correlation calculated for the first three axes of CCA includes: 0.80, 0.64, and 0.59. The Monte Carlo permutation test showed that the relationship was non-significant (Figure 3; Table 6; $P = 0.49$).

Table 2. The recorded woody species in the study area

Family	Scientific name	Abbrev.	Life form
Aceraceae	*Acer campestre* L.	Acer cam	Ph
Caprifoliaceae	*Viburnum lantana* L.	Vibu lan	Ph
Corylaceae	*Corylus avellana* L.	Cory ave	Ph
Cornaceae	*Cornus mas* L.	Corn mas	Ph
Ebenaceae	*Diospyros lotus* L.	Dios lot	Ph
Fagaceae	*Quercus iberica* M.Bieb.	Quer ibe	Ph
Oleaceae	*Fraxinus excelsior* L.	Frax exc	Ph
Rosaceae	*Cerasus avium* (L.) Moench.	Cera avi	Ph
	Crataegus ambigua A.K.Becker.	Crat amb	Ph
	Malus orientalis Uglitzk.	Malu ori	Ph
	Mespilus germanica L.	Mesp ger	Ph
	Prunus divaricata Ledeb.	Prun div	Ph
	Rosa canina L.	Rosa can	Ph
	Sorbus torminalis (L.) Crantz	Sorb tor	Ph

Table 1. The recorded herbaceous species in the study area

Family	Scientific name	Abbreviations	Life form
Alliaceae	*Allium ursinum* L.	Alli urs	Geo
	Allium paradoxum (M.Bieb.) G.Don.	Alli par	Geo
Apiaceae	*Heracleum persicum* Desf.	Hera per	Hem
Aspleniaceae	*Phyllitis scolopendrium* (L.) Newman.	Phyl sco	Geo
	Asplenium adiantum lanceolatum Hoffm.	Aspl adi	Geo
Asteraceae	*Achillea millefolium* L.	Achi mil	Hem
	Centaurea hyrcanica Bornm.	Cent hyr	Hem
	Hieracium lactucella Wallr.	Hier lac	Hem
	Hieracium umbrosum Jord.	Hier umb	Hem
	Taraxacum officinale F. H. Wigg.	Tara off	Hem
Campanulaceae	*Campanula latifolia* L.	Camp lat	Hem
Caprifoliaceae	*Sambucus ebulus* L.	Samb ebu	Geo
Clusiaceae	*Hypericum androsaemum* L.	Hype and	Ch
Convolvulaceae	*Calystegia sepium* (L.) R.Br.	Calys sep	Geo
Cyperaceae	*Carex stenophylla* Wahlenb..	Care ste	Hem
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Kuhn.	Pter aqu	Geo
Fabaceae	*Lathyrus latifolius* L.	Lath lat	Hem
	Lathyrus laxiflorus Kuntze.	Lath lax	Hem
	Trifolium medium L.	Trif med	Hem
	Trifolium pratense L.	Trif pra	Hem
	Trifolium repens L.	Trif rep	Cr
	Vicia sativa L.	Vici sat	Hem
	Vicia orobus DC.	Vici oro	Hem
Lamiaceae	*Mentha pulegium* L.	Ment pul	Hem
	Nepeta involucrata Bornm.	Nepe inv	Hem
Liliaceae	*Convallaria majalis* L.	Conv maj	Geo
Orchidaceae	*Epipactis atrorubens* (Hoffm.) Besser.	Epip atr	Geo
Poaceae	*Dactylis glomerata* L.	Dact glo	Hem
	Echinochloa crus-galli (L.) P. Beauv.	Echi cru	Th
	Eremopoa persica (Trin.) Roshev.	Erem per	Th
Polygonaceae	*Rumex crispus* L.	Rume cri	Hem
Primulaceae	*Primula veris* L.	Prim ver	Hem
	Primula vulgaris L.	Prim vul	Hem
Ranunculaceae	*Actaea spicata* L.	Acta spi	Hem
	Primula vulgaris Huds.	Prim vul	Hem
Rosaceae	*Agrimonia eupatoria* L.	Agri eup	Hem
	Fragaria vesca L.	Frag ves	Hem
	Geum heterocarpum Boiss.	Geum het	Hem
Rubiaceae	*Galium aparine* L.	Gali apa	Th
	Galium odoratum Scop.	Gali odo	Geo
	Galium rotundifolium L.	Gali rot	Geo
Scrophulariaceae	*Veronica hederifolia* L.	Vero hed	Th
Violaceae	*Viola alba* Besser.	Viol alb	Hem

Table 3. Monte Carlo test results, analyzing eigenvalue significance for herbaceous species

Axis	Eigenvalue	Mean	Minimum	Maximum	*P*
1	0.26	0.19	0.12	0.26	0.006
2	0.18	0.14	0.09	0.22	
3	0.12	0.11	0.07	0.17	

Table 4. Monte Carlo test results, analyzing herbaceous species abundance distribution-soil correlation

Axis	Correlation	Mean	Minimum	Maximum	*P*
1	0.94	0.88	0.72	0.97	0.03
2	0.87	0.84	0.70	0.95	
3	0.83	0.82	0.65	0.94	

Table 5. Monte Carlo test results, analyzing eigenvalue significance for woody species

Axis	Eigenvalue	Mean	Minimum	Maximum	*P*
1	0.05	0.04	0.02	0.07	0.3
2	0.02	0.03	0.01	0.05	
3	0.01	0.01	0.00	0.03	

Table 6. Monte Carlo test results, analyzing woody species abundance distribution-soil correlation

Axis	Correlation	Mean	Minimum	Maximum	*P*
1	0.80	0.80	0.65	0.98	0.49
2	0.64	0.73	0.55	0.93	
3	0.59	0.65	0.46	0.86	

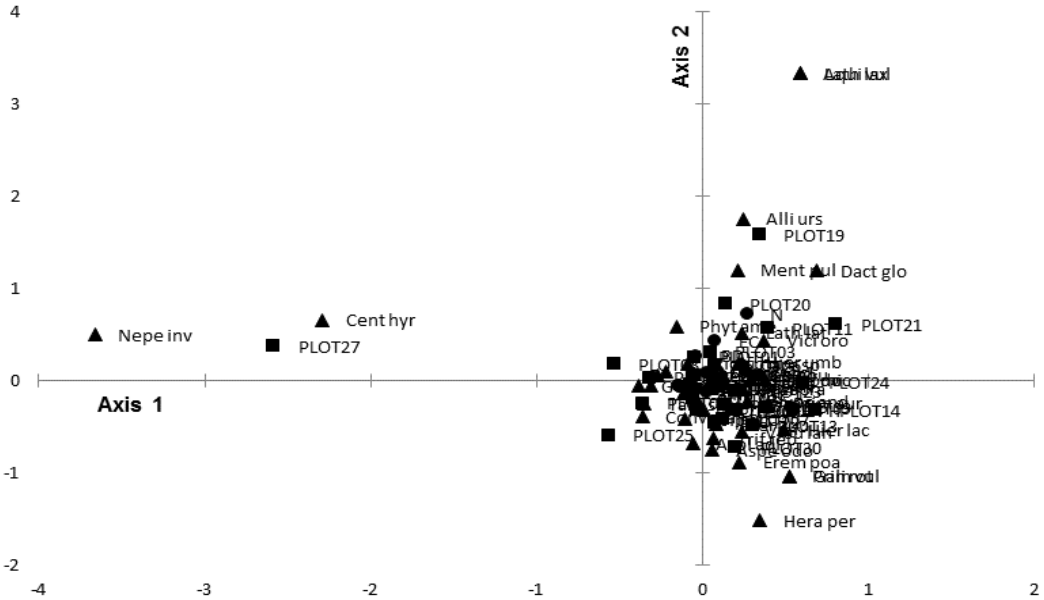

Figure 2. CCA-ordination diagram of herbaceous species abundance distribution related to soil physical and chemical properties. EC (electrical conductivity), OC (organic carbon), pH (acidity), SP (saturation moisture percentage), N (nitrogen), P (phosphorus), K (potassium), PD (particle density), S (sand), Si (silt), Cl (clay), and BD (bulk density). The triangles represent species, circles represent soil factors, and squares represent plots.

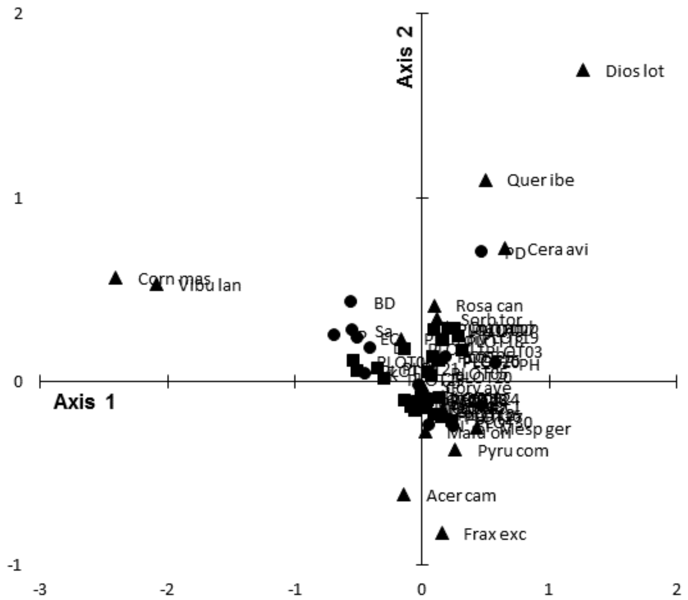

Figure 3. CCA-ordination diagram of woody species abundance distribution related to soil physical and chemical properties. EC (electrical conductivity), OC (organic carbon), pH (acidity), SP (saturation moisture percentage), N (nitrogen), P (phosphorus), K (potassium), PD (particle density), S (sand), Si (silt), Cl (clay), and BD (bulk density). The triangles represent species, the circles represent soil factors, and the squares represent plots

Discussion

The study of relationships between vegetation and environmental factors gives valuable knowledge of why certain plant species are found in some locations but not in others (Ravanbakhsh and Moshki 2016). This knowledge can help us in afforestation planning and biodiversity conservation in mountainous areas of northern Iran. A total of 43 herbaceous and 15 woody species belonging to 23 and 8 families were identified in the forest stand. The most species-rich families were the Asteraceae, Fabaceae, and Rosaceae, with 4, 3, and 11 genera and 5, 7, and 11 species, respectively.

The soil physical and chemical properties have a significant influence on plants growth and development

(Muenchow et al. 2013; Qian et al. 2014; An et al. 2015), and plants mutually play clear and predictable role in determining the soil nutrient (Fu et al. 2015; Novak et al. 2017). The soil properties cause heterogeneity over space and time and regulate the vegetation abundance (Silva and Batalha 2008; Brinkmann et al. 2009; Otýpková et al. 2011; Zhang et al. 2015). According to the previous researches, some soil variables have been identified as a determinant of species abundance distribution, for example, pH (Rodríguez-Loinaz et al. 2008; Hofmeister et al. 2009; Laganière et al. 2009; Royer-Tardif and Bradley 2011; Haberl et al. 2012; Pourbabaei and Adel 2015; Ullah et al. 2015), available K and total N (Qian et al. 2014; An et al. 2015), organic matter (Liu et al. 2012), rock content and bulk density (Wang et al. 2016), soil depth (Zhang et al. 2016), phosphorus content and electrical conductivity (Khan et al. 2016), concentration levels of K, Ca, P, CEC, and fertility index (Nadeau and Sullivan 2015), and CEC, OM, Fe, P, Mg, pH, Mn, Pb, Zn, Cu, sand, and clay proportion (Vincent and Meguro 2008).

The results showed the significant influence of some soil properties on the abundance of herbaceous species within the forest stand. The abundance of herbaceous species was closely correlated with the soil properties including pH and total N, while, we found no relationship between the woody species abundance and soil properties. This result may be due to many woody species are capable of growing across a wide range of soil or it seems that factors other than soil features are influential in the woody species abundance in the forest stand.

In conclusion, Our results provided information about plant diversity and the relationship between plant species abundance and soil physical and chemical properties in the common hazel forest of northern Iran. The distribution of vegetation largely depends on the capacity of plants to adopt resistance strategies in order to colonize the different soil conditions. The results indicated that a total of 43 herbaceous and 15 woody species belonging to 23 and 8 families were identified in the study area. The most species-rich families were the Asteraceae, Fabaceae, and Rosaceae, with 4, 3, and 11 genera and 5, 7, and 11 species, respectively. The herbaceous species abundance distribution was strongly correlated with soil properties, including the soil pH and total N. Furthermore, there was no correlation between the woody species abundance distribution and soil factors.

REFERENCES

Acosta A, Ercole S, Stanisci A, Pillar VDP, Blasi C. 2007. Coastal vegetation zonation and dune morphology in some mediterranean ecosystems. J Coast Res 23: 1518-1524.

An P, Li X, Zheng Y, Eneji AE, Qiman Y, Zheng M, Inanaga S. 2015. Distribution of plant species and species-soil relationship in the east central Gurbantunggut Desert, China. J Geogr Sci 25 (1): 101-112.

Bouyoucos GJ. 1962. Hydrometer method improved for making particle size analyses of soils. Agron J 54: 464-465.

Brevik EC, Cerdà A, Mataix-Solera J, Pereg L, Quinton JN, Six J, Van Oost K. 2015. The interdisciplinary nature of soil. Soil 1: 117-129.

Brinkmann K, Patzelt A, Dickhoefer U, Schlecht E, Buerkert A. 2009. Vegetation patterns and diversity along an altitudinal and a grazing gradient in the Jabal al Akhdar Mountain range of northern Oman. J Arid Environ 73: 1035-1045.

Cencini M, Pigolotti S, Muñoz MA. 2012. What ecological factors shape species-area curves in neutral models?. Plos One. doi: 10.1371/journal.pone.0038232

Cox A, Taylor RW, Raeburn H. 1993. Comparison of extractants for determination of available P, K, and Ca in some Grenada soils. Trop agr 70: 22-26.

Flowers TH, Bremner JM. 1991. A rapid dichromate procedure for routine estimation of total nitrogen in soils. Commun Soil Sci Plan 22: 1409-1416.

Fu B, Qi YB, Chang QR. 2015. Impacts of revegetation management modes on soil properties and vegetation ecological restoration in degraded sandy grassland in farming-pastoral ecotone. Int J Agr Biol Eng 8: 26-34.

Gazer M. 2011. Vegetation composition and floristical diversity in date palm orchards of Central Saudi Arabia. Acta Bot Hung 53: 111-126.

Ghaderi Sh, Amirian Chekan A, Karimzadeh A, Difarakhsh M, Pourrezaie J. 2017. The relationships between vegetation and soil factors using multivariate analysis (Case study: Chamran summer rangelands, Khuzestan province). Iran J Range Desert Res 24: 478-493.

Good RD'O. 1931. A theory of plant geography. New Phytol 30: 149-171.

Haberl H, Steinberger JK, Plutzar C, Erb KH, Gaube V, Gingrich S, Krausmann F. 2012. Natural and socioeconomic determinants of the embodied human appropriation of net primary production and its relation to other resource use indicators. Ecol Indic 23: 222-231.

Hofmeister J, Hošek J, Modrý M, Roleček J. 2009. The influence of light and nutrient availability on herb layer species richness in oak-dominated forests in central Bohemia. Plant Ecol 205: 57-75.

Ihlen PG, Gjerde I, Satersdal M. 2001. Structural indicators of richness and rarity of epiphytic lichens on *Corylus avellana* in two different forest types within a nature reserve in south-western Norway. Lichenologist 33: 215-229.

Johnson BG, Verburg PSJ, Arnone JA. 2014. Effects of climate and vegetation on soil nutrients and chemistry in the Great Basin studied along a latitudinal-elevational climate gradient. Plant Soil 382: 151-163.

Keesstra SD, Geissen V, Mosse K, Piiranen S, Scudiero E, Leistra M, van Schaik L. 2012. Soil as a filter for groundwater quality. Curr Opin Env Sust 4: 507-516.

Keymer DP, Lankau RA. 2017. Disruption of plant-soil-microbial relationships influences plant growth. J Ecol 105: 816-827.

Khan W, Mulk Khan S, Ahmad H, Ahmad Z, Page S. 2016. Vegetation mapping and multivariate approach to indicator species of a forest ecosystem: A case study from the Thandiani sub Forests Division (TsFD) in the Western Himalayas. Ecol Indic 71: 336-351.

Kirkpatrick JB, Green K, Bridle KL, Venn SE. 2014. Patterns of variation in Australian alpine soils and their relationships to parent material, vegetation formation, climate and topography. Catena 121: 186-194.

Laganière J, Paré D, Bradley RL. 2009. Linking the abundance of aspen with soil faunal communities and rates of belowground processes within single stands of mixed aspen-black spruce. Appl Soil Ecol 41: 19-28.

Lee RN, Bradfield GE, Krzic M, Newman RF, Cumming WFP. 2014. Plant community-soil relationships in a topographically diverse grassland in southern interior British Columbia, Canada. Botany 92: 837-845.

Liu W, Chen S, Qin X, Baumann F, Scholten T, Zhou Z, Sun W, Zhang T, Ren J, Qin D. 2012. Storage, patterns, and control of soil organic carbon and nitrogen in the northeastern margin of the Qinghai-Tibetan Plateau. Environ Res Lett 7: 35401-35412.

Lo IM, Tsang DC, Yip TC, Wang F, Zhang W. 2011. Influence of injection conditions on EDDS-flushing of metal-contaminated soil. J Hazard Mater 192: 667-675.

Marcuzzo SB, Araújo MM, Longhi SJ. 2013. Structure and environmental relations of floristic groups in tropical deciduous forest fragment. Rev Arvore 37: 275-287.

McCune B, Grace JB, Urban DL. 2002. Analysis of ecological communities. Mjm Software Design, Gleneden Beach, Oregon.

Miyamoto K, Suzuki E, Kohyama T, Seino T, Mirmanto E, Simbolon H. 2003. Habitat differentiation among tree species with small-scale variation of humus depth and topography in a tropical heath forest of central Kalimantan, Indonesia. J Trop Ecol 19: 43-54.

Montoya JM, Raffaelli D. 2010. Climate change, biotic interactions and ecosystem services. Philos T R Soc B 365: 2013-2018.

Muenchow J, Hauenstein S, Bräuning A, Bäumler R, Rodríguez EF, von Wehrden H. 2013. Soil texture and altitude, respectively, largely determine the floristic gradient of the most diverse fog oasis in the Peruvian desert. J Trop Ecol 29: 427-438.

Nadeau MB, Sullivan TP. 2015. Relationships between plant biodiversity and soil fertility in a mature tropical forest, Costa Rica. Int J Forestry Res. DOI: 10.3965/j.ijabe.20150801.004

Noumi Z. 2015. Effects of exotic and endogenous shrubs on understory vegetation and soil nutrients in the south of Tunisia. J Arid Land 7: 481-487.

Novak E, Carvalho LA, Santiago EF, Portilho IIR. 2017. Chemical and microbiological attributes under different soil cover. Cerne 23: 19-30.

Olsen SR, Sommers LE. 1982. Phosphorus. In: Page AL (eds). Agronomy monograph, methods of soil analysis. Part 2. Chemical and microbiological properties. American Society of Agronomy, Soil Science Society of America, Wisconsin.

Otýpková Z, Chytrý M, Tichý L, Pechanec V, Jongepier JW, Hájek O. 2011. Floristic diversity patterns in the White Carpathians biosphere reserve, Czech Republic. Biologia 66: 266-274.

Peña-Claros M, Poorter L, Alarcón A, Blate G, Choque U, Fredericksen TS, Justiniano J, Leaño C, Licona JC, Pariona W, Putz FE, Quevedo L, Toledo M. 2012. Soil effects on forest structure and diversity in a moist and a dry tropical forest. Biotropica 44: 276-283.

Poorbabaei H, Poorrahmati G. 2009. Plant species diversity in loblolly pine (*Pinus taeda* L.) and Sugi (*Cryptomeria japonica* D. Don.) plantations in the western Guilan, Iran. Int J Biodivers Conserv 1: 38-44.

Pourbabaei H, Adel MN, 2015. Plant ecological groups and soil properties of common Hazel (*Corylus avellana* L.) stand in Safagashteh forest, north of Iran. Folia For Pol Ser A For 57: 245-250.

Pourbabaei H, Asgari F, Reif A, Abedi R. 2012. Effect of plantations on plant species diversity in the Darabkola, Mazandaran province, North of Iran. Biodiversitas 13: 72-78.

Price MF, Gratzer G, Duguma LA, Kohler T, Maselli D, Romeo R. 2011. Mountain Forests in a Changing World - Realizing Values, Addressing Challenges. Published by FAO/MPS and SDC, Rome.

Qian Z, Yu YC, Yu XP, Gao HD, Lu R, Zhang WY. 2014. Changes of vegetation characteristics and soil properties in Mu Us Sandy Land by aerial seeding afforestation. J Cent South Univ For Techn 34: 102-107.

Rankin MO, Semple WS, Murphy BW, Koen TB. 2007. Is there a close association between soils and vegetation? A case study from central western New South Wales. Cunninghamia 10: 199-214.

Ravanbakhsh H, Moshki A. 2016. The influence of environmental variables on distribution patterns of Irano-Turanian forests in Alborz Mountains, Iran. J Mt Sci 13: 1375-1386.

Rodríguez-Loinaz G, Onaindia M, Amezaga I, Mijangos I, Garbisu C. 2008. Relationship between vegetation diversity and soil functional diversity in native mixed-oak forests. Soil Biol Biochem 40: 49-60.

Royer-Tardif S, Bradley RL. 2011. Forest floor properties across sharp compositional boundaries separating trembling aspen and jack pine stands in the southern boreal forest. Plant Soil 345: 353-364.

Silva DM, Batalha MA. 2008. Soil-vegetation relationships in cerrados under different fire frequencies. Plant Soil 311: 87-96.

Silva DM, Batalha MA, Cianciaruso MV. 2013. Influence of fire history and soil properties on plant species richness and functional diversity in a neotropical savanna. Acta Bot Bras 27: 490-497.

Smith P, Cotrufo MF, Rumpel C, Paustian K, Kuikman PJ, Elliott JA, McDowell R, Griffiths RI, Asakawa S, Bustamante M, House JI, Sobocká J, Harper R, Pan G, West PC, Gerber JS, Clark JM, Adhya T, Scholes RJ, Scholes MC. 2015. Biogeochemical cycles and biodiversity as key drivers of ecosystem services provided by soils. Soil 1: 665-685.

Srinivasan MP, Bhatia S, Shenoy K. 2015. Vegetation-environment relationships in a South Asian tropical montane grassland ecosystem: restoration implications. Trop Ecol 56: 201-217.

Ter Braak CJF. 1986. Canonical correspondence analysis: A new eigenvector method for multivariate direct gradient analysis. Ecology 67: 1167-1179.

Ter Braak CJF, Šmilauer P. 2002. CANOCO reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5). Microcomputer Power, Ithaca, New York.

Thomas GW. 1996. Soil pH and soil acidity. In: Sparks DL (eds). Agronomy monograph, methods of soil analysis. part 3. chemical methods. American Society of Agronomy, Soil Science Society of America, Wisconsin.

Thompson MM, Lagerstedt HB, Mehlenbache SA. 1996. Hazelnuts. In: Janick J, Moore JN (eds). Fruit breeding, vol 3, Nuts. John Wiley & Sons, New York.

Toure D, Ge J-W, Zhou J-W. 2015. Interactions between soil characteristics, environmental factors, and plant species abundance: A case study in the Karst Mountains of Longhushan Nature Reserve, southwest China. J Mt Sci 12: 943-960.

Ullah Z, Ahmad M, Sher H, Shaheen H, Khan SM. 2015. Phytogeographic analysis and diversity of grasses and sedges (Poales) of northern Pakistan. Pak J Bot 47: 93-104.

Van Reeuwijk LP. 1992. Procedures for Soil Analysis. International Soil Reference and Information Centre, the University of Wisconsin - Madison.

Vincent RDC, Meguro M. 2008. Influence of soil properties on the abundance of plant species in ferruginous rocky soils vegetation, southeastern Brazil. Rev Bras Bot 31: 377-388.

Vockenhuber EA, Scherber C, Langenbruch C, Meißner M, Seidel D, Tscharntke T. 2011. Tree diversity and environmental context predict herb species richness and cover in Germany's largest connected deciduous forest. Perspect Plant Ecol 13: 111-119.

Wang J, Wang H, Cao Y, Bai Z, Qin Q. 2016. Effects of soil and topographic factors on vegetation restoration in opencast coal mine dumps located in a loess area. Sci Rep-Uk. Doi: 10.1038/srep22058

Zhang J, Zhang B, Qian Z. 2015. Functional diversity of *Cercidiphyllum japonicum*, communities in the Shennongjia Reserve, central China. J Forestry Res 26: 171-177.

Zhang JT, Zhang M, Mian R. 2016. Effects of elevation and disturbance gradients on forest diversity in the Wulingshan Nature Reserve, North China. Environ Earth Sci 75: 904-1003.