Effect of soil and physiographic factors on ecological plant groups in the eastern Elborz mountain rangeland of Iran

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Introduction

The appearance of a plant group in a given area isn’t accidental, but occurs in response to changes in climatic, topographic, edaphic and biotic parameters. In fact, vegetation groups are determined by the combined effects of a whole range of ecological factors. Thus, change in the soil, topography and grazing factors can lead to vegetation responses in each area of the landscape (Holechek et al. 1989). Jangman et al. (1995) showed that vegetation ordination can be used to generate the ecological factor classes in each site. Plant species that appear in similar regions have equal ecologic requirements and can be defined as “ecological species groups”. The regions that contain similar ecological species groups create ecological groups that are homogeneous habitats with similar ecologic and floristic composition, which can be used in habitat classification (Zahedi and Mohammadi 2002; Kashian 2003; Kooch et al. 2008).

Ecologists use multivariate analyses to understand and identify complex relationships between ecological factors and their interactions in ecosystems. Some of these methods for investigation of relationships between plant species or communities with ecological parameters are direct and indirect gradient analyses (Jangman et al. 1987; Zahed 1998; Villers-rauiz et al. 2003; Jalilvand et al. 2007). In direct gradient analysis, ecological data ordination is based on
vegetation data and plant species distribution in relation to ecological parameters, whereas indirect gradient analysis is based on floristic data analysis without the effect of ecological factors. The ecological factors will be apparent only after analysis of floristic change. The ecological data are entered into the analysis in the interpretation step (Austin 1968; Moghaddam 2001; Jafari Jelodar 2008).

Use of new numerical methods and development of ordination techniques has improved understanding of plant communities and ecological parameter interactions. Nowadays, detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) techniques have been identified as important and practical methods of direct and indirect gradient analyses (Mesdaghi 2005).

The DCA method is an indirect method to show species correlation. This method arranges vegetation data based on their presence or absence in sampling plots and shows species group locations at each site. First, this method calculates the magnitude of species composition change in the first ordination axis (lengths of gradient). Based on the calculated gradient, the type of analysis to be used for ordination is determined ($\geq 3$ for CCA, $<3$ for RDA). Species group separation is clearer in DCA. Furthermore, a group’s border isn’t always identifiable in CCA or RDA. Although, for determining the relationship between species and environmental data, direct methods are the best methods of ordination, DCA is more useful in species grouping (Hill and Gauch 1980; Jean and Bouchard 1993). The combination of CCA and RDA is the complement of DCA. These new techniques select the linear combination of environmental variables that maximize species scores, whereas CCA chooses the best weights for the environmental variables (Zahedi 1998). This gives the first CCA axis. In CCA, composite gradients are linear combinations of environmental variables, giving a much simpler analysis that provides a summary of the species–environment relationships. In vector diagrams, vector lengths show the efficacy of each factor, with a longer length indicating a stronger relationship. Also, closeness of species to a vector shows its responsiveness to that factor. Occurrence of a species near a vector indicates a positive relationship with that factor and its diminished relationship with the other factors (Jangman et al. 1987; Ghorbani et al. 2003).

Use of these methods in different studies has defined associations of plant species that have been used to create ecological groups in response to a complex collection of soil characteristics (Bui and Henderson 2003; Jafari et al. 2004; Abd El-Ghani and El-Sawaf 2005) or a mixture of physiographic, climatic and edaphic factors (Clark and Mann 1999; Sneddon 2001; Evans and Levin 2004; Mohtashamnia et al. 2008). Grazing management and plant competition also have important roles in determining inter-species associations (Marc et al. 2003; Lenssen et al. 2004). The ecological grouping method has been used in several ecosystems such as rain and temperate forests, coastal plains, desert regions and wetlands (Clark and Mann 1999; Diane and Maureen 2004; Omer 2004; Monier 2006; Päivi 2006; Li et al. 2008) or in long-term studies (Lameire 2000).

Interactions between plant groups and environmental parameters provide a useful opportunity to alter management to improve rangeland ecosystems. Thus, DCA and CCA multivariate analyses were used in this research to investigate the effect of edaphic and physiographic factors that formed ecological plant groups in the east of the Elborz mountain rangeland of Iran. The main purpose of the present study was to determine the strongest factors affecting the separation of plant groups. Identification of these parameters in a given ecosystem helps us to apply appropriate management for restoration and development in the present and in similar regions.

Materials and methods

Study area

The Elborz Mountains are located near the south of the Caspian Sea in northern Iran. The site studied is a cold and semirid summer rangeland area in the east of the Elborz mountain range ($54^\circ04'30"-54^\circ09'10"$W, $36^\circ29'28"-36^\circ31'45"$N; Figure 1). Mean annual precipitation is 380 mm of which 70% is snow, and mean annual temperature is 12.4°C. Elevation ranges between 2000 and 2700 m a.s.l. Vegetation comprises grasses, shrubs and bushy trees and some cultivated plants on the rangeland borders.

Sampling methods and analysis

To investigate the relationship between vegetation, and physiographic and edaphic characteristics, topographical (1 : 25,000) and lithological maps (1 : 100,000) of the area were used in the first step. Then, the information layers of slope, aspect, hypsography and lithology were created in GIS (Arc View 3.3). The geomorphologic land units ($n = 66$) map was obtained by overlaying the slope, aspect, hypsometric and lithologic layers (Figure 2). From these land units, with similar lithology and altitude (2100–2200 m a.s.l.) but contrasting slopes and aspects, were selected. Some of the selected units shown in Figure 2 were merged because of their close similarities in most factors. Except in one land unit where 40 plots were sampled, sampling was conducted at 30 randomly chosen plots of 1 m$^2$ within each of the nine land units. Size and number of plots were obtained by minimal area and statistical methods, respectively (Kent and Coker 1996). Topographic (slope and aspect) and vegetative characteristics (species names, cover, density and frequency percentage) were
recorded by visual scores and subsequent calculations within each plot. Aspect data were calculated by angle conversion to northing: \( \text{Heat Load} = \left[1 - \cos(\theta - 45)\right]/2 \) where \( \theta \) is the aspect value based on 360° with the highest heat being in the southwest quadrant. Soil samples were taken from 0–20 cm and 20–50 cm depths in each plot. Sub samples from well-mixed soil layers were analyzed for texture (Gee and Bauder 1982), calcium carbonate (Nelson 1982), organic matter (Nelson and Sommers 1982), bulk density (Black and Hartge 1982), total nitrogen (Bremner and Mulvaney 1982), available phosphorus (Olsen and Sommers 1982) and available potassium (Knudson and Peterson 1982).

For data analysis, DCA, CCA techniques and partial variance analysis were used in Canoco 4.0 software (Mesdaghi 2005). Where length of gradient in DCA analysis was \( \geq 3 \), then CCA was used for further analyses. Interpretation of CCA was done using species grouping in DCA. Significant correlations between species and environment factors were tested by Monte Carlo test (with 99 frequencies), \( P \)-value and \( F \)-ratio. Where significant relationships were found, two dimensional diagrams of species and environmental parameters were developed (Jangman et al. 1995). Finally, the impact of soil, topography and their combined impact on landscape variation were calculated by partial variance analysis (Lepz and Smilauer 2003).

**Results**

The DCA analysis showed that the components of variation could be expressed in four axes (Table 1). The cumulative percentage variance of species data were significant, ranging between 36.5 in Axis 1 to 54.7 in Axis 4. These results revealed that there was a significant difference between the four main plant groups which are well separated by correlation.

The species distribution diagram (Figure 3) shows that the ordination on the first two axes showed separation into four plant groups, with component species being:

Group 1 exotic forbs: Centaurea solstitialis, Cirsium arvense, Eryngium caeruleum, Euphorbia cheiradenia, Gundelia tournefortii, Marrubium vulgare, Phlomis herba-venti, Stachys byzantina, Stachys inflate and Taraxacum vulgare.

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Figure 1 Location of study area in the eastern Elborz Mountain region of Iran.
Group 2 native grasses: *Agropyron elongatum*, *Bromus tomentellus*, *Bromus tectorum*, *Stipa barbata*, *Festuca ovina*, *Melica persica*, *Hordeum fragile*, *Dactylis glomerata* and *Dianthus orientalis*.

Group 3 native shrubs, forbs and conifers: *Juniperus sabina*, *Juniperus communis*, *Acantholimon pterostegium*, *Acanthophylum crassifolium*, *Onobrychis cornuta*, *Astragalus vereskensis*, *Astragalus gossypinus*, *Astragalus parrowianus*, *Salvia officinalis*, *Thymus kotschyanus*, *Thymus pubescence*, *Thymus volgare*, *Verbascum thapsus*, *Teucrium polium* and *Achillea millefolium*.

Group 4 native broadleaf bushy trees: *Cerasus pseudo-prostrata* and *Cotoneaster nummularioides*.

The origin of the species and the abbreviations used in the tables and figures are shown in Appendices I and II.

Most of these species are correlated with a positive vector in the first and second axes. Based on species group’s distribution, the first and third Groups and a part of the second Group are located within the positive vector axes. The fourth Group is located in the positive vector of the first axis and the negative vector of the second axis (Figure 3).

Aspects was shown in CCA analysis (Table 2) to have the strongest correlation (0.84) with the first axis. The other factors such as nitrogen (N), organic carbon (OC), potassium (K) (in sub soil), calcium carbonate (CaCO₃), a measure of

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**Table 1** Results of detrended correspondence analysis (DCA)

| Axes | 1     | 2     | 3     | 4     | Total inertia |
|------|-------|-------|-------|-------|--------------|
| Eigenvalues | 0.581 | 0.373 | 0.281 | 0.235 | 1.590        |
| Lengths of gradient | 4.888 | 3.718 | 3.110 | 3.063 |              |
| Cumulative percentage of species data | 36.5  | 47.4  | 52.5  | 54.7  |              |

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Figure 2 Map of geomorphological land units in the study area. Nine land units (13, 25, 28, 43, 46, and 8 and 9 merged, 6 and 37 merged, 18 and 20 merged, and 14, 17 and 19 merged) having similar lithology and altitude, but different slope and aspect were chosen, from which 30 plots were sampled for species composition.
alkalinity) and slope have significant correlation with this axis, whereas correlations with the second axis are moderate for components of soil texture (sand, silt and clay percentage).

The species distribution in the CCA diagram (Figure 4) most likely influenced how species were allocated into the four distinct groups, which is revealed by DCA. In view of the species reaction to the different factors based on their position in the landscape, the results showed that: Group 1 exotic forbs is closest to the origin, indicating that it has a balanced amount of influence from all soil components and GIS factors; Group 2 natives grasses are normally found in places with a northern aspect, flat slope, and with higher K, N and OC; Group 3 native shrubs, forbs and conifers tend to occur on higher slopes, but with a southern aspect with higher Ca and P; Group 4 tends to grow on clay and silt soils, not sandy soil.

Results of partial variance (Table 3) showed that 69.6% of rangeland composition changes were explainable by the soil and topographic parameters. Among these, 48.9% belonged to soil, 15.5%, topography and 5.2% common effect of them.

**Discussion**

The results of DCA analysis show that different plant species are found in contrasting ecologic zones. Environmental factors have an important effect on plant species distribution in this area as they have separated the species into distinct ecological groups. The effect of some environmental factors appeared to influence the presence or absence of some species within plots and their grouping among plots. This DCA analysis approach has also been used in other studies to effectively identify species group’s reactions to ecological factors effects (Guisan and Zimmermann 2000; Diane and Maureen 2004; Monier 2006; Li et al. 2008).

The plant species reaction to abiotic factors in CCA analyses show that each species has reacted to one or several edaphic or topographic factors. In this case, the Group 1 invader species demonstrated the least reaction to these factors because the species of this group were all located close to the origin of coordinates and were not along the environmental gradient in two axes. However, these species were located some distance along the soil texture (silt and clay) and bulk density vectors (Figure 4). Also, their distribution is inversely related to soil elements (N, P, K), OC, sand, aspect and slope vectors. There were invader species such as *Cirsium arvense*, *Centaurea solstitialis*, *Gundelia tournefortii*, *Eryngium caeruleum*, *Marrubium vulgare*, *Phlomis herba-venti*, *Euphorbia cheiradenia*, *Taraxacum vulgare* and two species of *Stachys* genus in this group that *Stachys* spp. and *Euphorbia cheiradenia* are native plants but others are exotic. This is indicative of the intensive grazing pressure on this habitat since grazing animals deplete soil fertility in this environment (Toit et al. 2009). Moreover, low P soils on moderate slopes are likely caused by fertility transfer to flatter sites (Arzani et al. 2007). Livestock trampling under intensive grazing habitats has also increased soil bulk density (Han et al. 2008) and probably resulted in a mix of topsoil and subsurface soils as seen by the altered physical, chemical
Table 2 Correlation values ($R$) of variables with axes in canonical correspondence analysis (CCA)

| Abiotic variables | First axis | Second axis |
|-------------------|------------|-------------|
| Bulk density$_a$ | 0.0286 | 0.1415 |
| Bulk density$_b$ | $-0.2205$ | $0.1274$ |
| Clay$_a$ | $0.0996$ | $0.3720$ |
| Clay$_b$ | $0.1047$ | $0.3220$ |
| Silt$_a$ | $0.0195$ | $0.4308$ |
| Silt$_b$ | $0.1362$ | $0.3950$ |
| Sand$_a$ | $-0.0842$ | $-0.4787$ |
| Sand$_b$ | $-0.1333$ | $-0.4520$ |
| CaCO$_3_a$ | $-0.4331$ | $0.1859$ |
| CaCO$_3_b$ | $-0.3338$ | $0.1207$ |
| OC$_a$ | $0.1759$ | $-0.2426$ |
| OC$_b$ | $0.5733$ | $-0.2997$ |
| Na | $0.1341$ | $-0.2431$ |
| Nb | $0.4888$ | $-0.2761$ |
| P$_a$ | $-0.1702$ | $0.1326$ |
| P$_b$ | $-0.2260$ | $-0.2021$ |
| K$_a$ | $0.1412$ | $-0.0061$ |
| K$_b$ | $0.5438$ | $0.0753$ |
| C/Na | $0.1783$ | $-0.2281$ |
| C/Nb | $0.0446$ | $-0.1553$ |
| Slope | $-0.3947$ | $-0.2448$ |
| Aspect$^\dagger$ | $0.8376$ | $-0.2410$ |

$^\dagger$a, topsoil (0–20 cm); b, subsoil (20–50 cm).

$^\dagger$Northing based on $[1 - \cos(\theta - 45)]/2$.

and biological properties, each of which can influence seed germination and survival (De Falco et al. 2009). On the other hand, the absence of distinct relationships between this group of invader species and abiotic factors is related to the absence of similar environmental factors because the effect of intensive grazing (as a human factor) has invoked other environmental factors, which have rearranged the ecological balance in these sections (Ghorbani et al. 2003; Jafari et al. 2004). This finding confirms that of Andrieu et al. (2007) which found that invader species become abundant in these landscapes irrespective of local ecological conditions.

The species in Group 2 belong to grasses. Abundance of these species is positively influenced by N, K, OC and C/N of soil, and aspect, but negatively influenced by CaCO$_3$ (alkaline soils), whereas subsoil bulk density had little impact. Abundance of grass species had no positive correlation to soil texture or slope, as the grasses were indifferent to slopes and soil texture. Because these grass species are sensitive to high grazing pressure, their distribution is restricted to low-intensity grazed landscapes, where soil fertility (nitrogen, potassium and organic matter) is sufficient to support good pasture production (Xie and Wittig 2004). This is likely because grazing stimulates plant regrowth and absorption of soil nutrients. Also, erosion in intensively grazed landscapes depletes soil elements and decreases soil

![Figure 4](https://example.com/figure4.png) Correspondence between plant species and environment factors in canonical correspondence analysis (CCA). The further a point is from the origin, the greater is the influence of that factor(s) on the plant's presence. The closer the point is to an axis line, the stronger is the influence of that factor, relative to another factor, on the species presence in that part of the landscape.
fertility (Dormaar and Willms 1998; Hosseinzadeh 2006). Animal treading damage can result in decreased soil porosity (increased soil bulk density). This limits sustainability of sensitive species such as grasses in more heavily grazed sites (Arzani et al. 2007). On the other hand, while not measured in this experiment, a higher soil moisture content on northern aspects (in the northern hemisphere) should improve conditions for grass abundance (Taghipour 2005; Mirdavoodi et al. 2007). High soil pH (high CaCO₃) is also a known limiting factor for growth of grasses (Jafari et al. 2003). In conclusion, we believe the grasses in Group 2 (Figure 3) are so grouped, as a response to high soil fertility, low pH, high soil moisture regime and low grazing intensity.

Group 3 includes cushion plants (such as Onobrychis cornuta and Astragalus spp.), coniferous bushy trees (Juniperus sabina and Juniperus communis) and some shrubs (such as Thymus spp.) that are strongly responsive to increasing slope and higher soil pH. The present study confirms that these species are found in steep, alkaline soils (Zarehchahooki et al. 2001; Esmaeelzadeh et al. 2007; Haghian et al. 2008; Mohtasham nia et al. 2008).

Group 4 broadleaf bushy tree species, respond positively to finer soil texture. This response probably relates to a higher soil moisture requirement of these species because they are dominant on north and north-western faces and on low slopes with fine textured soils that hold more water than coarse-textured soils. These landscapes maintain a higher soil moisture regime than southern aspects, causing broad-leaved species to abound (Zahedi and Mohammadi 2002; Shokri et al. 2003; Khademolhosseini et al. 2007).

The analysis of partial variance (Table 3) showed a changing percentage of the factors that we studied impact rangeland composition. Soil (49%) and topographic (15%) factors explain much of the total variance relating to whether ecological groups are present in the landscape. The combined effect of soil and topography explains only a further approximately 5% of the plant groups presence in the landscape. Therefore, Axis 1 was relates to slope, aspect and soil organic matter, while Axis 2 represents soil texture (sand, silt and clay, Figure 4). We assume that the remaining variation arose from biotic factors (especially grazing).

Table 3 Percentage of environmental parameters that explain rangeland species composition differences

| Source of variation | Trace (variance) | Total inertia† | Percent of explained variation (trace/total inertia × 100) |
|---------------------|-----------------|---------------|----------------------------------------------------------|
| Topography (T)      | 0.246           | 1.59          | 15.5                                                     |
| Soil (S)            | 0.777           | 1.59          | 48.9                                                     |
| Combined effect (C) | 0.083           | 1.59          | 5.2                                                      |
| Total (T + S + C)   | 1.106           | 1.59          | 69.6                                                     |

†Total inertia from Table 1.

Although grazing was not considered a variable in these analyses, the effect of grazing on plant composition and soil properties in the landscape is undeniable (Han et al. 2008; Pei et al. 2008). This grazing effect appears to account for the appearance of Group 1 species as invader species.

Conclusions

The present study showed that at one given altitude in this cold and semi-arid, mountain rangeland, the effect of aspect and slope and soil properties played an important role in determining plant community composition. Also, an apparently high grazing intensity (increased bulk density and elevated soil fertility status) increased soil compaction and decreased the presence of the native grasses. These changes, with physiographic effects, are important reasons for variations in soil fertility. These effects result in changing vegetation communities, which includes the opportunity for ingress of invader plants. Plant community species alter ecological relationships that can create new landscapes. Identification of these species and understanding of their relationships with environmental parameters can help range management planning. In this way, the use of multivariate analyses (DCA and CCA) can be useful to describe species variation. In new research, grazing intensity should also be measured and used as an environmental variable in these multivariate analyses.

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References

Abd El-Ghani MM, El-Sawaf NA (2005) The coastal roadside vegetation and environmental gradients in the arid lands of Egypt. Community Ecol 6: 143–154.

Andrieu N, Josien E, Duru M (2007) Relationship between diversity of grassland vegetation, field characteristics and land use management. Agric Ecosystems Environ 120: 359–369.

Arzani H, Abedi M, Shahrayar E, Ghorbani M (2007) Investigation of soil surface indicators and rangeland functional attributes by grazing intensity and land cultivation (case study: Orazan Taleghan, Iran). Range Desert Res 14: 68–79 (In Persian with English abstract.)

Austin MP (1968) An ordination study of a chalk-grassland community. J Ecol 56: 739–757.

Black CR, Hartge KH (1982) Bulk density. In: Methods of Soil Analysis (Ed Klue, A), American Society of Agronomy, Madison, Wisconsin, 363–376.

Bremner JM, Mulvaney CS (1982). Total nitrogen. In: Methods of Soil Analysis (Eds Page AL, Miller RH, Keeney DR),
American Society of Agronomy, Madison, Wisconsin, 595–624.

Bui E, Henderson BL (2003) Vegetation indicators of salinity in northern Queensland. *Aust Ecol* 28: 539–552.

Clark DB, Mann VI (1999) Edaphic factors and the landscape scale distribution of tropical rain forest trees. *J Ecol* 80: 2662–2675.

De Falco LA, Esque TC, Kane JM, Nicklas MB (2009) Seed banks in a degraded desert shrubland: influence of soil surface condition and harvester ant activity on seed abundance. *J Arid Environ* 73: 885–893.

Diane DS, Maureen MT (2004) Vegetation of upper coastal plain depression wetlands. *J Wetl* 24: 23–42.

Dormaar JF, Willms WD (1998) Effect of forty-four years of grazing on fescue grassland soils. *J Range Manage* 51: 122–126.

Esmaeilzadeh A, Hosseini SM, Tabari M (2007) Investigation of *Tussac bucca* communities in Afra-Takhtieh site, Iran. *Pajoohesh and Sazandegi* 74: 17–24. (In Persian with English abstract.)

Evans JM, Levin SA (2004) *Vegetation Classification and Mapping of Peoria Wildlife Area, South of New Melones Lake, Tuolumne County, California*. California Native Plant Society, Tuolumne.

Gee GW, Bauder JW (1982) Particle size analysis. In: *Methods of Soil Analysis* (Ed Klue A), American Society of Agronomy, Madison, Wisconsin, 383–412.

Ghorbani J, Das PM, Hughes JM, Mc Allister HA, Pallai SK, Pakeman RJ, Marrs RH, Le Duc MG (2003) Effect of restoration treatments on the diaspore bank under dense *Pteridium* stands in the U.K. *Appl Veg Sci* 6: 189–198.

Guisan A, Zimmermann NE (2000) Predictive habitat distribution models in ecology. *Ecol Model* 135: 147–186.

Haghiyan A, Ghorbani J, Shokri M, Jafarian Z (2008) Use of ordination technique in study of relation between vegetation and climatic factors (case study; Savadkooh summer rangelands, Iran). In: *Proceedings of 1st International Conference on the Caspian Region Environmental Changes*, Babolsar, Iran, 24–25 August 2008, 110–117. (In Persian with English abstract.)

Han G, Hao X, Zhao M, Wang M, Ellert BH, Willms W, Wang M (2008) Effect of grazing intensity on carbon and nitrogen in soil and vegetation in a meadow steppe in Inner Mongolia. *Agric Ecosyst Environ* 125: 21–32.

Hill MO, Gauch HG (1980) Detrended correspondence analysis: an improved ordination technique. *J Veg* 42: 47–58.

Holechek JL, Pieper RD, Herbel CH (1989) *Range Management. Principles and Practices*. Prentice-Hall, New Jersey.

Hosseinazadeh G (2006) Investigation and comparison of vegetation cover changes and some characteristics of soil in grazed and ungrazed rangeland in Eskelimroud of Iran (PhD Thesis). University of Mazandaran, Sari. (In Persian with English abstract.)

Jafari M, Zare Chahouki MA, Tavili A, Azarnivand H (2004) Effective environmental factors in the distribution of vegetation types in Poshtkouh rangelands of Yazd Province, Iran. *J Arid Environ* 56: 627–641.

Jafarian Jelodar Z (2008) Spatial modeling of rangeland vegetation types using ecological indicators and satellite data (PhD Thesis). University of Tehran, Tehran. (In Persian with English abstract.)

Jalilvand H, Kooch Y, Bahmanyar MA, Pormajidian MR (2007) Ecological species groups of hornbeam forest ecosystems in southern Caspian (north of Iran). *Pak J Biol Sci* 7: 1504–1510.

Jangman RHG, Ter Braak CJG, Van Tongeren OFR (1987) *Data Analysis in Community and Landscape Ecology*. Fire Agricultural Publishing and Documentation, Wageningen.

Jangman RHG, Ter Braak CJG, Van Tongeren OFR (1995) *Data Analysis in Community and Landscape Ecology*. Cambridge University Press, Cambridge.

Jean M, Bouchard A (1993) Riverine wetland vegetation: importance of small-scale and large-scale environmental variation. *J Veg Sci* 4: 609–620.

Kashian DM (2003) Ecological species groups of landform level ecosystems dominated by jack pine in northern Lower Michigan, USA. *Plant Ecol* 66: 75–91.

Kent M, Coker P (1996) *Vegetation Description and Analysis. A Practical Approach*. John Wiley and Sons press, New York.

Khademolhosseini Z, Shokri M, Habibian SH (2007) Effect of topographic and climatic factors on vegetation distribution in Arsanjan rangelands, Iran. *Rangeland* 3: 222–235. (In Persian with English abstract.)

Knudson D, Peterson GA (1982) Lithium, sodium and potassium. In: *Methods of Soil Analysis* (Ed Page AL), American Society of Agronomy, Madison, Wisconsin, 225–246.

Kooch Y, Jalilvand H, Bahmanyar MA, Pormajidian MR (2008) Application of two way indicator species analysis in lowland plant types classification. *Pak J Biol Sci* 11: 752–757.

Lameire S (2000) Two decades of change in the ground vegetation of a mixed deciduous forest in an agricultural landscape. *J Veg Sci* 11: 695–704.

Lenssen JPM, Menting FBJ, Van der PWH (2004) Do competition and selective herbivory cause replacement of *Phragmites australis* by tall forbs. *J Aquat Bot* 78: 217–232.

Lepz J, Smilauer P (2003) *Multivariate Analysis of Ecological Data using Canoco*. Cambridge University Press, Cambridge.

Li WQ, Xiao-Jing L, Ajmal Khan M, Gul B (2008) Relations between the most important ecological factors and vegetation description and analysis of *Pteridium* stands in the U.K. *Plant Ecol* 2010: 329–334.

Marc TV, Jean-Paul O, Annie G, Jean-Claude G, Jean-Claude G (2003) *Data Analysis in Community and Landscape Ecology*. Cambridge University Press, Cambridge.

Mirdavoodi HR, Zahedi H, Shakoee M, Tourkan J (2007) Relations between the most important ecological factors and...
rangeland vegetative using of multivariate data analysis methods (case study: South of Markazi province, Iran). *Iran J Range Desert Res* 13: 201–211.

Moghaddam MR (2001) Quantitative Plant Ecology. Tehran University Press, Tehran. (In Persian.)

Mohtasham nia S, Zahedi Gh, Arzani H (2008) An investigation on synecology of semi-steppe vegetation in relation to edaphic and physiographical factors (Case study: Eghlid rangelands of Fars, Iran). *Agri Sci Nat Resour* 14: 111–123 (In Persian with English abstract.)

Monier M (2006) Vegetation associates of the endangered *Randomia africana* and its soil characteristics in an arid desert ecosystem of western Egypt. *Acta Bot Croat* 65: 83–99.

Nelson RE (1982) Carbonate and gypsum. In: *Methods of Soil Analysis* (Ed Page AL), American Society of Agronomy, Madison, Wisconsin, 181–198.

Nelson DW, Sommers LE (1982) Total carbon, organic matter and organic carbon. In: *Methods of Soil Analysis* (Ed Page AL), American Society of Agronomy, Madison, Wisconsin, 539–580.

Olsen SR, Sommers LE (1982) Phosphorous. In: *Methods of Soil Analysis* (Eds Page AL, Miller RH, Keeney DR), American Society of Agronomy, Madison, Wisconsin, 403–430.

Omer LS (2004) Small-scale resource heterogeneity among halophytic plant species in an upper salt marsh community. *Aquat Bot* 78: 337–348.

Päivi H (2006) Vegetation patterns of boreal herb-rich forests in the Koli region, eastern Finland: classification, environmental factors and conservation aspects (PhD Thesis), University of Joensuu, Finland.

Pei S, Fu H, Wan C (2008) Changes in soil properties and vegetation following enclosure and grazing in degraded Alxa desert steppe of Inner Mongolia, China. *Agric Ecosyst Environ* 124: 33–39.

Shokri M, Bahmanyar MA, Tatian MR (2003) An ecological investigation of vegetation covers in estival rangelands of Hezarjarib, Iran. *Nat Resour* 56: 131–142. (In Persian with English abstract.)

Sneddon L (2001) *Vegetation Classification of Fire Island National Seashore*. TNC/ABI Vegetation Mapping Program. Association for Biodiversity Information, Boston MA, USA.

Taghipour A (2005) The effect of climatic factors on plant distribution in Hezarjarib summer rangelands, Iran (MSc Thesis), University of Gorgan, Gorgan. (In Persian with English abstract.)

Toit GN, Snyman HA, Malan PJ (2009) Physical impact of grazing by sheep on soil parameters in the Nama Karoo subshrub/grass rangeland of South Africa. *J Arid Environ* 73: 804–810.

Villers-ruiz L, Trejo VI, Lopez BJ (2003) Dry vegetation in relation to the physical environment in the Baja California, Mexico. *Veg Sci* 14: 517–524.

Wang Y, Wittig R (2004) The impact of grazing intensity on soil characteristics of *Stipa grandis* and *Stipa bungeana* steppes in northern China (autonomous region of Ningxia). *Acta Oecol* 25: 197–204.

Zahedi Gh (1998) Relation between ground vegetation and soil characteristics in a mixed hardwood stand (PhD Thesis), University of Gent, Belgium.

Zahedi Gh, Mohammad S (2002) Relationship between plant ecological groups in herbal layer and forest stand factors (Case study: Neka forest, Iran). *Nat Resour* 55: 341–355. (In Persian with English abstract.)

Zarehchahooki MA, Jafari M, Azarnivand H, Baghestani N, Tavili A (2001) Ordination of rangeland vegetation in related to physical and chemical soil characteristics (Case study: Yazd Poshtkooh rangelands, Iran.) In: *Proceedings of the 17th WCSS Conference*, 14–21 Aug. 2001, Thailand, 247–259.

## Appendices

### Appendix I Plant species characteristics

| No. | Scientific name               | Life form | Native/Exotic | Abbreviation |
|-----|------------------------------|-----------|---------------|--------------|
| 1   | *Acantholimon pterostegium*  | Shrub     | Native        | Aca.pte      |
| 2   | *Acanthophyllum crassifolium*| Shrub     | Native        | Aca.cra      |
| 3   | *Achillea millefolium*       | Forb      | Native        | Ach.mil      |
| 4   | *Agropyron elongatum*        | Grass     | Native        | Agr.elo      |
| 5   | *Astragalus gossypinus*      | Shrub     | Native        | Ast.gos      |
| 6   | *Astragalus parrowianus*     | Shrub     | Native        | Ast.par      |
| 7   | *Astragalus vereskensis*     | Shrub     | Native        | Ast.ver      |
| 8   | *Bromus tectorum*            | Grass     | Native        | Bro.tec      |
| 9   | *Bromus tomentellus*         | Grass     | Native        | Bro.tom      |
| 10  | *Centareua solstitialis*     | Shrub     | Exotic        | Cen.sol      |
| 11  | *Cerasus pseudoprostrata*    | Bushy tree| Native        | Cer.pse      |
| 12  | *Cirsium arvense*            | Forb      | Exotic        | Cir.arv      |
| 13  | *Cotoneaster nummularioides* | Bushy tree| Native        | Cot.num      |
| 14  | *Dactylis glomerata*         | Grass     | Native        | Dac.glo      |
### Appendix 1

**Continued**

| No. | Scientific name            | Life form | Native/Exotic | Abbreviation |
|-----|----------------------------|-----------|---------------|--------------|
| 15  | *Dianthus orientalis*      | Forb      | Native        | Dia.ori      |
| 16  | *Eryngium caeruleum*      | Forb      | Exotic        | Ery.cae      |
| 17  | *Euphorbia cheiradenia*    | Forb      | Native        | Euph.che     |
| 18  | *Festuca ovina*           | Grass     | Native        | Fes.ov       |
| 19  | *Gundelia tournefortii*   | Forb      | Exotic        | Gun.tou      |
| 20  | *Hordeum fragile*         | Grass     | Native        | Hor.fra      |
| 21  | *Juniperus communis*      | Bushy tree| Native        | Jun.com      |
| 22  | *Juniperus sabina*        | Bushy tree| Native        | Jun.sab      |
| 23  | *Marrubium vulgare*       | Forb      | Exotic        | Mar.vul      |
| 24  | *Melica persica*          | Grass     | Native        | Mel.per      |
| 25  | *Onobrychis cornuta*      | Shrub     | Native        | Ono.cor      |
| 26  | *Phlomis herba-venti*     | Forb      | Exotic        | Phi.her      |
| 27  | *Salvia officinalis*      | Forb      | Native        | Sal.off      |
| 28  | *Stachys byzantina*       | Forb      | Native        | Sta.byz      |
| 29  | *Stachys inflata*         | Forb      | Native        | Sta.inf      |
| 30  | *Stipa barbata*           | Grass     | Native        | Sti.bar      |
| 31  | *Taraxacum vulgare*       | Forb      | Exotic        | Tar.vul      |
| 32  | *Teucrium polium*         | Forb      | Native        | Teu.pol      |
| 33  | *Thymus kotschyanus*      | Shrub     | Native        | Thy.kot      |
| 34  | *Thymus pubescence*       | Shrub     | Native        | Thy.pub      |
| 35  | *Thymus vulgare*          | Shrub     | Native        | Thy.vul      |
| 36  | *Verbascum thapsus*       | Forb      | Native        | Ver.tha      |

### Appendix II

Explanation of the soil parameter abbreviations in the text

| Parameter | Explanation                                    | Parameter | Explanation                           |
|-----------|-----------------------------------------------|-----------|---------------------------------------|
| bd<sub>a</sub> | Bulk density in top soil                     | OC<sub>a</sub> | Organic carbon in top soil           |
| bd<sub>b</sub> | Bulk density in sub soil                     | OC<sub>b</sub> | Organic carbon in sub soil           |
| Clay<sub>a</sub> | Clay in top soil                             | N<sub>a</sub> | Nitrogen in top soil                 |
| Clay<sub>b</sub> | Clay in sub soil                             | N<sub>b</sub> | Nitrogen in sub soil                 |
| Silt<sub>a</sub> | Silt in top soil                             | P<sub>a</sub> | Phosphorus in top soil               |
| Silt<sub>b</sub> | Silt in sub soil                             | P<sub>b</sub> | Phosphorus in sub soil               |
| Sand<sub>a</sub> | Sand in top soil                             | K<sub>a</sub> | Potassium in top soil                |
| Sand<sub>b</sub> | Sand in sub soil                             | K<sub>b</sub> | Potassium in sub soil                |
| Ca<sub>a</sub> | CaCO<sub>3</sub> in top soil                | C/N<sub>a</sub> | Carbon/Nitrogen ratio in top soil    |
| Ca<sub>b</sub> | CaCO<sub>3</sub> in sub soil                | C/N<sub>b</sub> | Carbon/Nitrogen ratio in sub soil    |