ENVIRONMENTAL GRADIENTS ACROSS WETLAND VEGETATION GROUPS IN THE ARID SLOPES OF WESTERN ALBORZ MOUNTAINS, N. IRAN

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ABSTRACT

Mountain wetlands are unique ecosystems in the arid southern slopes of Alborz range, the second largest range in Iran. The spatial distribution characteristics of wetland vegetation in the arid region of the Alborz and the main factors affecting their distributional patterns were studied. A classification of vegetation and ecological characteristics were carried out using data extracted from 430 relevés in 90 wetland sites. The data were analyzed using Two Way Indicator Species Analysis (TWINSPAN) and detrended correspondence analysis (DCA). The wetland vegetation of Alborz Mountain was classified into four large groups. The first vegetation group was calcareous rich vegetation, mainly distributed in the river banks and characterized by helophytes such as *Bolboschoenus affinis* as indicator species. The second group was saline transitional vegetation, distributed in the ecotone areas and dominated by *Phragmites australis*. The third vegetation group is wet meadow vegetation which mainly consists of geophytes, endemic and Irano-Turanian species, distributed in the higher altitudes. This vegetation is mainly characterized by indicator species such as *Carex orbicularis*, high level concentration of Fe^{2+} and percentage of organic matter in the soil. The fourth vegetation group is aquatic vegetation, distributed in the lakeshores. The aquatic group species are mainly hydrophytic such as *Batrachium trichophyllum*. The TWINSPAN vegetation groups could be also recognized in the DCA graphs and ecologically differentiated by ANOVA of studied variables. Four vegetation groups can be differentiated on two first axes of indirect ordination. There is a gradient of pH, EC and organic matter associated with altitude on the DCA diagram. Correlation analysis between the axes of DCA and environmental factors shows that altitude, soil texture and other dependant environmental variables (e.g. pH) are the main environmental factors affecting the distribution of wetland vegetation groups.

KEY WORDS: altitudinal gradient, dry mountain wetlands, vegetation ordination, Western Alborz range, Iran.

INTRODUCTION

Studies focusing on wetlands of Alborz Montains, the second largest in Iran are parts of on-going ecological research on dry mountain wetlands of Iran. Iran is a mountainous country which most of its vegetation covered by steppes. The Mountain wetlands of the southern slopes of Western section of Alborz are from environmental view point sharply differentiated from the adjacent arid steppe ecosystems. Despite their relatively small and scattered area, they are extremely important contributors to plant species diversity within Irano-Turanian phytogeographical region (sensu Zohary 1973). Studies relating to interrelationships between vegetation, habitat diversity and ecological factors have been the subject of many ecological studies in recent years (Hájková et al. 2006; Pinto et al. 2006; Rolon and Maltchik 2006; Hájek et al. 2008; Hájek et al. 2009; Victoria 2009). Most of the latter studies are related to wetland vegetation especially ones of mountain ecosystems (Gerdol and Tomaselli 1993).

Most studies on the flora and vegetation of the Alborz range have been conducted particularly in the Central and Eastern sections (Klein and Lacoste 1995; Klein 2001; Nazarian et al. 2004; Jafari and Akhani 2008; Naqinezhad et al. 2009). Therefore, detailed ecological and floristic accounts remain very scarce, particularly for the wetland sites in the western section.

The primary aim is to acquire more insight into vegetation and ecological properties of the wetland habitats in the Alborz Mountains. Other objectives of the study are: 1) to distinguish the main vegetation groups across mountain wetlands; 2) to find the spatial distribution pattern of wetland vegetation; 3) to indicate differential environmental characters among the vegetation groups; 4) International comparison of this investigation within Irano-Turanian and Euro-Sibirian regions.

MATERIALS AND METHODS

Study site

The study area corresponds to the southern part of the Western Alborz Mountains, located between 49°24´ and 51°19´ E and between 35°56´ and 36°45´ N. (Fig. 1). This sector, which is nearly 250 km long and 70 km wide, rises on Mount Siahlan to 4170 m high. Altitude ranges from 350 m to 3200 m. Study sites were varied in area from 200 m^2 to more than 10 ha (86.5 ha in total). The Alborz interpose between Hindu Kush-Himalaya Mountains in the east and Anatolia and Caucasus Mountains in the west. Therefore, this transition area exhibits some very important phytogeographical aspects.

Eocene volcanic and volcaniclastic rocks form the most prominent geological feature of the southern section of the Alborz Mountains. However, in northern section of the Alborz, Middle Jurassic to Upper Cretaceous limestone formations become much more important and form some very high rock cliffs along the East-West directed thrust fault zones (Stöcklin 1974).

The study area exhibits temperate and continental climates in the low and high altitudes respectively. The climatic data show that the higher altitudes of Alborz are affected by the north-westerly flow of polar air masses (Khalili 1973). The summer is arid, warm and sunny with intensive radiation most of the time. Water supply during the arid season is derived mainly from melting snow and springs. Annual amplitudes of temperature can be high. At 1500 m, the mean annual temperature is 13°C, that of January – 0.6°C and that of August 26°C. Precipitation is more abundant on the northern slope, influenced by the Caspian Sea, than on the more continental southern slope. At 1500 m, the mean annual rainfall is 370 mm a^{-1}, that of September 130 mm a^{-1} and that of March 480 mm a^{-1}. The precipitation amounts and the length of the drought period vary across the region. Stations located at lower altitudes have a more extended period of drought, rather lower precipitation and higher mean annual temperatures than is found at higher stations. All temperature values decrease with altitude. Unfortunately, there are no meteorological data from higher elevations.

Vegetation and floristic data

Ninety wetland study sites on the southern slopes of the western Alborz Mt were selected (Fig. 1).The study was carried out within the period of 2005 to 2007. The vascular flora were recorded in 430 relevés across the 90 study wetland sites and then identified in the central herbarium of Tehran University (TUH). The collection of relevés followed the Braun-Blanquet approach (Braun-Blanquet 1964). The sample area for most relevés was 1-4 m^2. The number of relevés and their size were related to site area and followed the minimal area. Nomenclature for vascular plants was based on Rechinger (1963-2005).

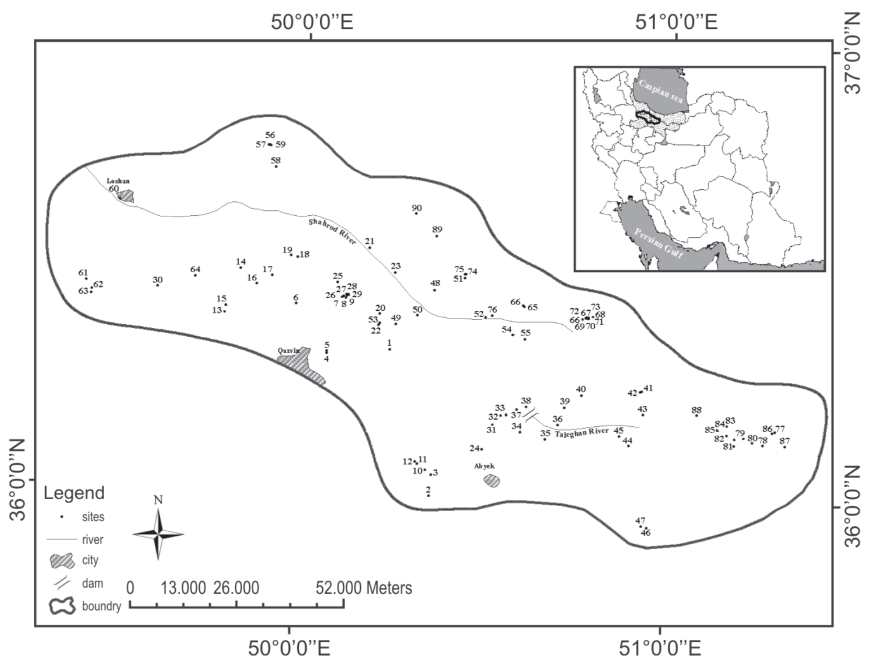

Fig. 1. Location of the study wetland sites in the western Alborz Mts (Iran).

Species characters

Studied variables are classified into two groups, including; species-related variables group (life-form, phytogeographical information) and environmental variables group (altitude, slope, soil physical and chemical properties). Following Raunkiaer life-forms (Raunkiaer 1934) were separated: chamaephyte, geophyte, helophyte, hemicryptophyte, hydrophyte, phanerophyte and therophyte. The geographical distribution of each species was assessed based on data obtained from monographs and distributional data in the floras, particularly Flora Iranica (Rechinger 1963-2005). The terminology and delimitation of the main phytogeographic areas (i.e. Euro-Siberian (ES), Irano-Turanian (IT), Mediterranean (M) and Pontic province within Euro-Siberian region (PON)) relates to standard reference works, particularly those of Zohary (1973) and Takhtajan (1986). The classification of phytogeographical elements into four categories is applicable in the current work to provide summary data with appropriately-sized groupings for statistical analysis. PE_1 'broadly pluriregional'; PE_2 'narrowly pluriregional' (plants found in two or three phytogeographic regions); PE_3 'Irano-Turanian' (includes both Irano-Turanian sensu stricto (IT) and Irano-Turanian-Pontic (IT-PON) floristic elements); PE_4 'endemic' (includes endemic species or subendemic species).

Site and relevé attributes

Soil cores (five replicates per studied wetland site) were collected at random to a depth of 10 cm. Soil samples were mixed to reduce heterogeneity and air-dried prior to analysis. Measured soil variables include physical and chemical properties. Soil texture (the proportions of sand, silt and clay) was determined by the hydrometer method (Bouyoucus 1951). Soil pH in a suspension of 1:2.5 or 1:5 soil: water ratio at 20°C and EC in a saturation extract at 20°C were determined by pH meter glass electrode and EC meter respectively. They were subsequently crushed and sieved through a 2 mm mesh. Organic matter was estimated by the Walkley and Black's method (Nelson and Sommers 1996) and the proportion of $CaCO_3$ was measured by the Calcimeter method (Allison and Moode 1965). The measurements of extractable cations of Potassium (K^+), Calcium (Ca^{2+}), Sodium (Na^+) extracted with Ammonium acetate (NH_4OAc); Iron (Fe^{2+}) extracted with DTPA (diethylenetriaminepentaacetic acid) (Page 1982) were determined using ICP-emission spectroscopy (GBC Integra XL) (Dahlquist and Knoll 1978). The inclination of slope of the ground was subjectively assessed in the field. Altitude and coordinates were measured by GPS (Garmin 76CSx).

Data analysis

The variables matrix includes altitude, slope degree, percentages of each life-form and phytogeographic elements, sand, silt, clay, organic matter, $CaCO_3$ and pH, EC, Na^+, K^+, Ca^{2+}, Fe^{2+} for each site. Because of high number of relevés (430) and high expenses for analysis of total soil cores, soil data for each site were equally used for all relevés collected in the same site. Floristic analysis was performed with PC-ORD, V. 4.17 package (McCune and Mefford 1999). To identify species with particular diagnostic value, the floristic data of 430 relevés and 368 species were classified with the two-way indicator species analysis (TWINSPAN) (Hill 1979).

Canoco 4.5 for Windows (Ter Braak and Šmilauer 2002) was used for ordination analyses. An unconstrained ordination analysis (DCA) was applied to find the axes with maximum variation in floristic composition of studied sites and thus describe the general pattern in species distribution along the gradients (Lepš and Šmilauer 2003). The DCA diagram was subsequently passively projected with all variables to show their variation across the species data. The Kolmogorov-Smirnov test was used to approve the normal distribution of parametric variables. It was found necessary to square-transform of all studied variables except altitude, percentages of silt, sand, geophyte, hemicryptophyte, PE_1 and PE_3. The Pearson correlation coefficient was used to examine relationships between ordination scores for sites and the distribution of species and habitat variables. To study if the mean value of study factors changes significantly across the four vegetation end-groups, one-way ANOVA was used with differences between subsets assessed by *post-hoc* Tukey tests. Statistical tests are performed using SPSS for Windows™ (Version 16.0).

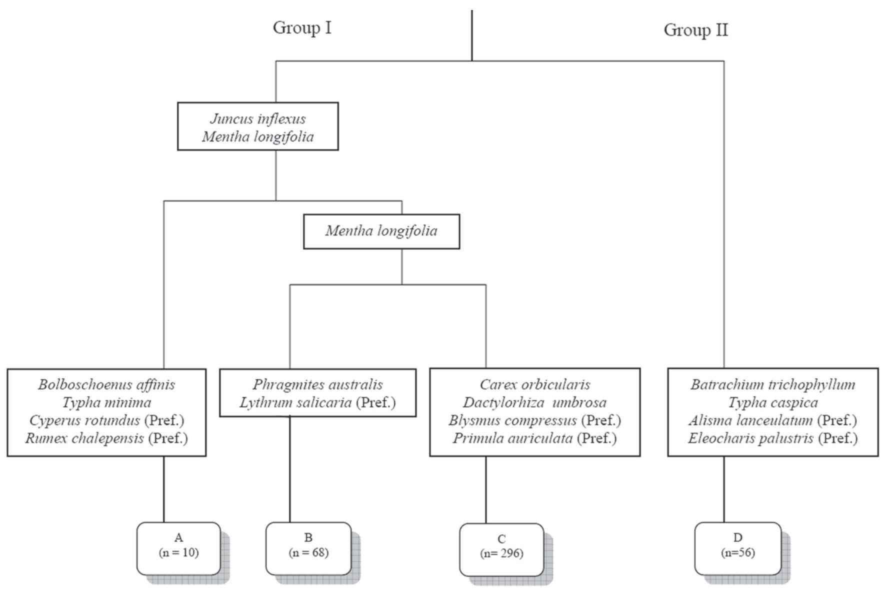

Fig. 2. The TWINSPAN dendrogram of relevés with indicator and preferential (Pref.) species. Vegetation groups were shown by capital letters. The number of relevés in each group is indicated in parentheses.

TABLE 1. Relative frequency (%) of species in the four vegetation groups defined by TWINSPAN. Only species with minimum 20% occurrence in a group are included.

Vegetation group	A	B	C	D
Bolboschoenus affinis	60	–	–	–
Calamagrostis pseudophragmites	30	–	–	–
Cyperus rotundus	30	–	–	–
Echinochloa crus-galli	20	–	–	–
Inula thapsoides	20	–	–	–
Juncus articulatus	40	–	33	–
Juncus inflexus	40	40	43	–
Lythrum salicaria	20	26	–	–
Paspalum disticum	30	–	–	–
Phragmites australis	30	81	–	32
Schoenoplectus lacustris	60	–	–	34
Schoenopletus mucronatus	30	–	–	–
Typha caspica	30	–	–	32
Typha laxmannii	40	–	–	–
Typha minima	50	–	–	–
Cirsium arvense	–	26	–	–
Lotus corniculatus	–	24	31	–
Mentha longifolia	–	28	65	–
Plantago lanceolata	–	31	–	–
Blysmus compressus	–	–	31	–
Carex orbicularis	–	–	33	–
Dactylorhiza umbrosa	–	–	29	–
Eleocharis uniglumis	–	–	23	–
Nasturtium officinale	–	–	21	–
Primula auriculata	–	–	30	–
Ranunculus polyanthemus	–	–	18	–
Trifolium pratense	–	–	30	–
Trifolium repens	–	–	31	–
Veronica anaglis-aquatica	–	–	20	–
Alisma lanceolatum	–	–	–	25
Batrachium trichophyllum	–	–	–	32

RESULTS

Major gradients in the wetland vegetations

The mountain wetland habitats of Alborz show a great range of vegetation variation. In the first division of TWINSPAN two major groups I and II were separated (Fig. 2). The indicator species of group I were *Juncus inflexus* and *Mentha longifolia* and ones of group II were *Batrachium trichophyllum, Schoenoplectus lacustris* and *Typha caspica.*

Here we refer to main plant groups without using phytosociological nomenclature. Four groups have been recognized at the three levels of TWINSPAN divisions (A, B, C and D). The species frequency of these groups is shown in Table 1, which includes only the most abundant ones. The first division of the TWINSPAN dendrogram generated a group of relevés (56 relevés) mainly in lake-shores (Group D) (Fig. 2, Tables 1 and 2). The indicator species such as *Batrachium trichophyllum* and *Typha caspica* characterize this group. This group of vegetation is much dominated by helophytes and hydrophytes species. *Alisma lanceolatum*, *Potamogeton lucens* and *Zannichelia palustris* are among the most important species occurring in this group.

Second division generated a group with ten relevés (Group A) characterized by the indicator species such as *Bolboschoenus affinis* and *Typha minima* (Fig. 2 and Table 1). This vegetation group, which mostly confined to river banks, is characterized with high proportion of large helophytic monocot species (up to 2 m height) (Table 2). The occurrence of some preferential species such as *Cyperus rotundus* and *Schoenoplectus mucronatus* differentiates this group from the rest.

At the third level of the division, group B (68 relevés) is negatively differentiated from the group C (296 relevés) by *Phragmites australis* and *Lythrum salicaria* and positively differentiated by *Carex orbicularis* and *Dactylorhiza umbrosa* as the indicator species (Fig. 2). Vegetation group C occupies wet meadow habitats. *Mentha longifolia* is the dominant species with higher cover-abundance. Other dominant species of this vegetation group are *Carex orbicularis, Dactylorhiza umbrosa, Blysmus compressus, Primula auriculata* and *Juncus articulatus.*

Vegetation groups defined in the TWINSPAN classification are also shown in the two first axes of DCA analysis (eigenvaules 0.59 and 0.34 for two first axes respectively) (Fig. 3). The gradient lengths of the two first axes were 7.59 and 6.69, respectively. The first axis is closely related to the gradient from group D toward group C (Fig. 3 and Table 2). Along axis 1, from the left-hand side

TABLE 2. Characteristic of TWINSPAN groups and their contribution within four studied wetland habitats.

Indicator species	Preferential species	Group	% occurrence in wetland habitats			
			River bank	Springside	Lakeshore	Wet meadow
Bolboschoenus affinis *Schoenoplectus lacustris* *Typha minima* *T. laxmannii*	*Cyperus rotundus* *Rumex chalepensis* *Schoenoplectus mucronatus*	A	80.0	0.00	10.0	10.0
Phragmites australis	*Cirsium arvense* *Lythrum salicaria* *Plantago lanceolata*	B	22.5	16.2	27.9	33.8
Carex orbicularis *Dactylorhiza umbrosa*	*Blysmus compressus* *Juncus articulates* *Primula auriculata* *Trifolium repens*	C	3.4	19.4	6.8	70.4
Batrachium trichophyllum *Typha caspica*	*Alisma lanceolatum* *Eleocharis palustris*	D	8.9	5.4	73.2	12.5

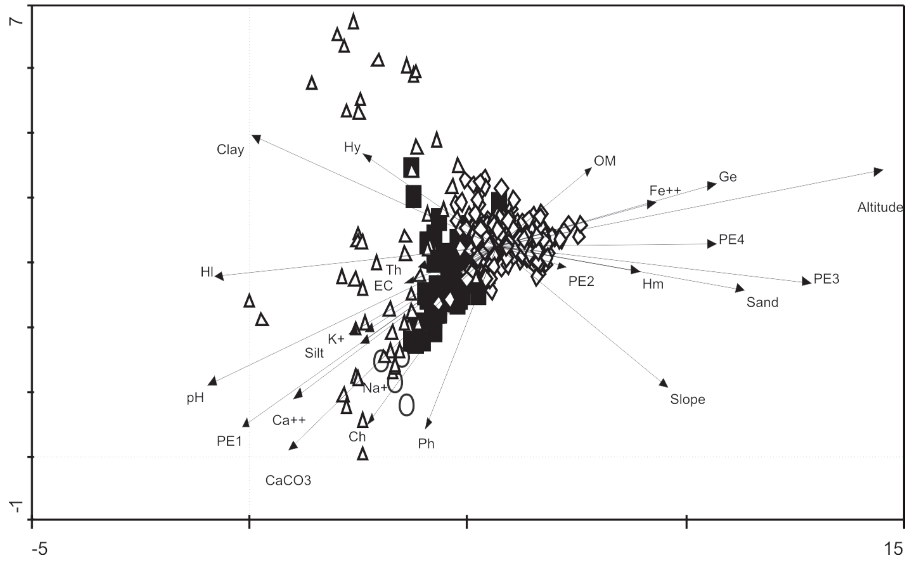

Fig. 3. DCA ordination of relevé of the western Alborz wetland vegetation groups. Environmental variables, phytogeographic and life-form data are passively projected onto the ordination diagram.
Group A (○); Group B (■); Group C (◊); Group D (Δ). Ch – chamaephyte; Ge – geophyte; Hl – helophyte; Hm – hemicryptophyte; Hy – hydrophyte; Ph – phanerophyte; Th – therophyte; OM – organic matter. $PE_{1\text{-}4}$ relates to the four phytogeographic categories (‘broadly pluriregional’, ‘narrowly pluriregional’, ‘Irano-Turanian’ and ‘endemic’, respectively) described in Material and methods.

to the right, the percentage of geophytes, PE_4 and PE_3 are increased, while the percentage of helophytes, hydrophytes and PE_1 are decreased (Fig. 3). The second axis is highly correlated ($p<0.001$) with percentage of chamaephyte. The vegetation group located on the furthermost end of this axis (Group C) was characterized by the presence of geophytes such as *Carex orbicularis* (as indicator species). In the opposite direction (near to center of graph), group A in lower altitude than the group C was dominated by the presence of some helophytes such as *Bolboschoenus affinis* and *Typha minima*. This group was seen mainly in the river banks (Table 2). Group B is located in transitional zone among the other groups and is characterized with the occurrence of *Phragmites australis* as indicator species (Fig. 3). Also, the DCA plot of species data indicates variation of floristic composition within studied sites across vegetation groups (Fig. 4).

Major trends in variation of environmental variables

According to the DCA analysis, the species-environmental correlation was 0.82 for axis 1 and 0.53 for axis 2, which indicates a good relationship between the species and the ecological characteristic of the vegetation groups. The first axis of DCA is highly correlated ($p<0.001$) with all variables (Table 3). Furthermore, the first axis ultimately refers to an altitudinal gradients associated with the correlated changes of other variables. Along axis 1 from the left-hand side to the right, with increasing of altitude, percentage of organic matter, sand and concentrations of Fe^{2+} are increased, while pH, percentage of clay are decreased (Fig. 3). The second axis is highly correlated ($p<0.001$) with pH, percentage of OM, concentrations of Na^+ and $CaCO_3$. Group C is located on habitats characterized by humic substrates (high organic matter) in higher elevation. Group A occupies calcareous habitats in the lower altitudes. Group B is located in transitional zone among the other groups and occupies saline habitats. In this group, *Phragmites australis* (as indicator species) is a euryhaline species that can be seen in many habitats. Hydrologic characteristics differentiae groups A and D, in the other word, depth of water is higher in group D, and fluctuation of water level is higher in group A.

ANOVA analysis between characters of four vegetation end-groups

The results of one-way ANOVA between the TWINSPAN groups indicate that all variables are significant in ANOVA that compares values from each of the four vegetation groups (Table 3). Group C was clearly differentiated from the rest by the highest value of altitude, slope degree, percentage of sand, organic matter, geophytes, hemicryptophytes, PE_3 and PE_4. Groups A and D have the most similarity to each other, but they were significantly differentiated by the percentage of helophytes and hydrophytes. Group B was significantly separated by altitude from groups A and D.

DISCUSSION

Major vegetation end-groups and species-related characters

The distribution of phytogeographic elements and life forms all differ according to different vegetation groups of western Alborz Montains (Table 3). This result is also shown in the indirect analysis of ordination (Fig. 3). This variation indicates the occurrence of different sets of floristic composition in these groups. Significant change of different life form across the vegetation groups can be related to altitude and other environmental variables (Kessler 2000; Klimeš 2003; Odland 2009). The low values of helophytes and hydrophytes in upper altitudes were explained by the steep topography and the lacking lakeshore and river bank habitats.

The phytogeographical pattern of wetland habitats in the Alborz differs from that of adjacent steppe ecosystems. The proportion of classified phytogeographical categories used in the paper (PE_1-PE_4) changes significantly across the vegetation groups. The most important phytogeographical aspect of these ecosystems is the high level of plurireginal phytogeographic elements in comparison with neighboring steppic vegetation which mainly dominated by Irano-Turanian elements (Zohary 1973; Klein 2001; Noroozi et al. 2008). More phytogeographically widespread species are confined mainly to the vegetation groups A and D in the lower

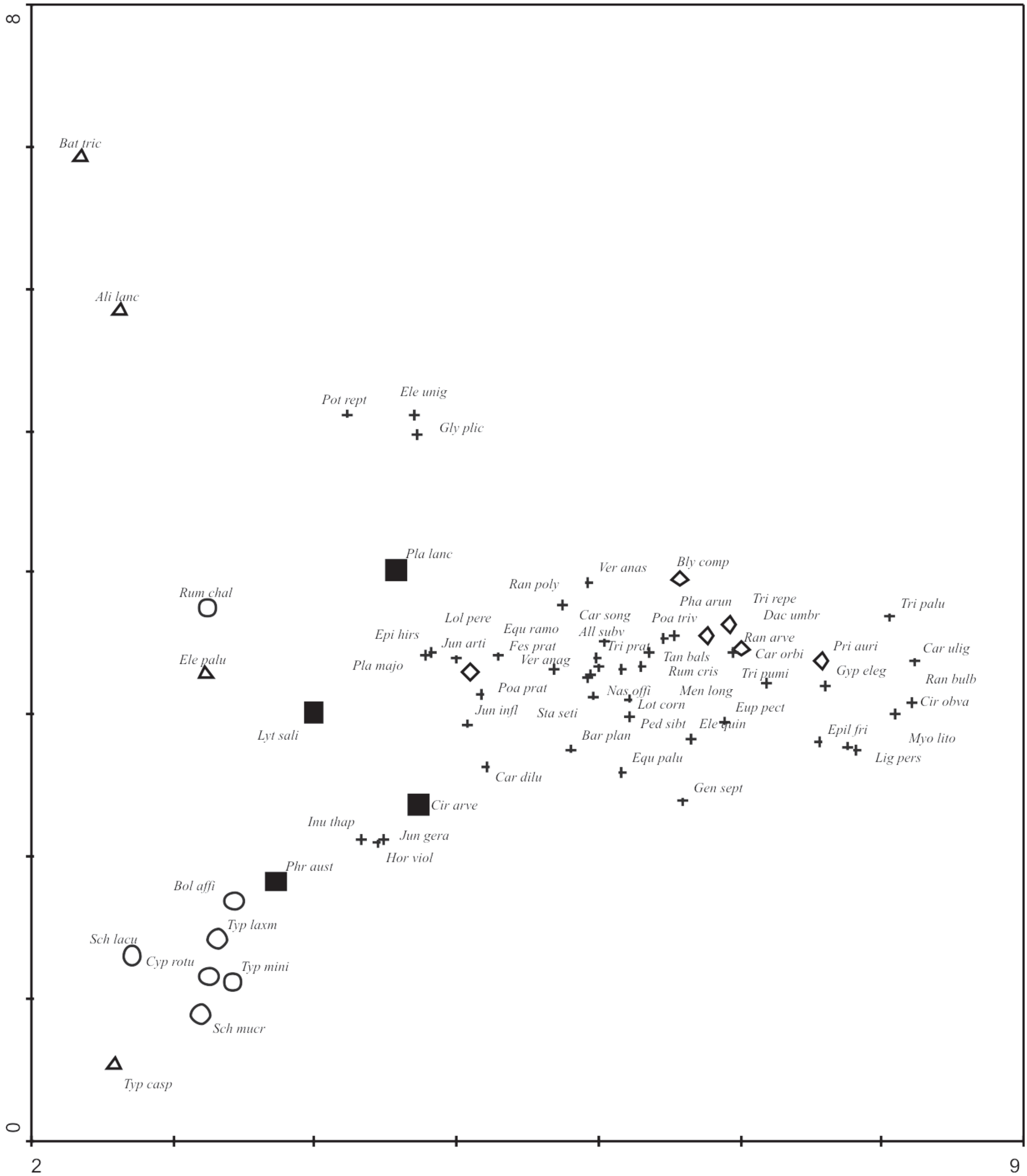

Fig. 4. DCA ordination of species in the western Alborz wetland vegetation. Indicator and preferential species of TWINSPAN classification are shown with different symbols: Group A (○); Group B (■); Group C (◊); Group D (Δ) and other species with (+). Species weight (3%) was used for the selection of the species in the plot. The species included in the diagram here abbreviated to the first three letters of the genus and the first four of the specific epithet are as follows:

Alisma lanceolatum, *Allium subvineale*, *Barbarea plantaginea*, *Batrachium trichophyllum*, *Blysmus compressus*, *Bolboschoenus affinis*, *Cardamine uliginosa*, *Carex diluta*, *C. orbicularis*, *C. songorica*, *Cirsium arvense*, *C. obvallatum*, *Cyperus rotundus*, *Dactylorhiza umbrosa*, *Eleocharis. palustris*, *E quinqueflora*, *E. uniglumis*, *Epilobium frigidium*, *E. hirsutum*, *Equisetum palustre*, *E.ramosissimum*, *Euphrasia pectinata*, *Festuca pratensis*, *Gentiana septemfida*, *Glyceria pelicata*, *Gypsophila elegans*, *Hordeum violaceum*, *Inula thapsoides*, *Juncus articulatus*, *J. gerardi*, *J. inflexus*, *Ligularia persica*, *Lolium perenne*, *Lotus corniculatus*, *Lythrum salicaria*, *Mentha longifolia*, *Myosotis litospermifolia*, *Nasturtium officinale*, *Pedicularis sibthorpii*, *Phalaris arundinacea*, *Phragmites australis*, *Plantago lanceolata*, *P. major*, *Poa pratensis*, *P. trivialis*, *Potentilla reptans*, *Primula auriculata*, *Ranunculus arvensis*, *R. bulbosus*, *R. polyanthemos*, *Rumex chalepensis*, *R. crispus*, *Schoenoplectus lacustis*, *S. mucronatus*, *Stachys setifera*, *Tanacetum balsamita*, *Trifolium pratense*, *T. repens*, *Triglochin palustre*, *Typha caspica*, *T. minima*, *T. laxmannii*, *Veronica anagalis-aquatica*, *V. anagallioieds.*

TABLE 3. Relationships between ordination axes, wetland vegetation groups, environmental and floristic variables. Pearson correlation coefficients between each variable and the first two DCA axes are followed by summary statistics (mean ± standard error and [Range]) P value, *F*-ratio from ANOVA of studied variables in each vegetation group within the Alborz Mountains. Groups with the same letters are not statistically significantly different from each other at p<0.05 in Tukey *post-ho* tests. *, ** and *** identify *p*<0.05, <0.01 and <0.001, respectively.

	DCA	DCA	A (n=10)	B (n=68)	C (n=296)	D (n=56)	*P*	F
	(axis 1)	(axis 2)	Mean ± SE [range]	Mean ± SE [range]	Mean ± SE [range]	Mean ± SE [range]		
Eigenvalue	0.59	0.34						
Environmental variables								
Altitude	0.56***	0.21***	1085.0±90.1^{a} [900.0-1800.0]	1550.0±51.9^{b} [350.0-2500.0]	2357.0±27.4^{c} [900.0-3200.0]	1852.9±57.6^{d} [900.0-2800.0]	0.000	85.4***
Slope inclination	0.46***	0.04	0.0±0.0^{ac} [0.0-0.0]	6.5±1.8^{a} [0.0-70.0]	14.7±0.9^{b} [0.0-70.0]	1.0±0.3^{c} [0.0-10.0]	0.000	45.1***
Silt (%)	-0.33***	-0.05	31.3±3.5^{a} [7.0-41.0]	28.6±1.2^{a} [10.0-53.0]	22.1±0.4^{b} [3.0-41.0]	27.4±1.1^{a} [7.0-53.0]	0.000	19.3***
Sand (%)	0.48***	0.08	22.4±8.0^{ab} [0.0-62.0]	33.6±2.3^{b} [0.0-66.0]	47.0±1.1^{c} [9.0-80.0]	24.3±2.0^{a} [0.0-62.0]	0.000	33.2***
Clay (%)	-0.45***	-0.03	46.3±6.4^{ab} [22.0-65.0]	37.6±1.6^{a} [17.0-65.0]	30.7±0.8^{c} [13.0-62.0]	48.1±2.0^{b} [17.0-71.0]	0.000	26.1***
OM (%)	0.21***	0.19***	1.3±0.5^{a} [0.4-4.2]	2.4±0.2^{a} [0.0-9.3]	6.1±0.4^{b} [0.0-41.2]	3.8±0.7^{a} [0.4-41.2]	0.000	17.0***
$CaCO_3$ (%)	-0.41***	-0.19***	16.9±1.1^{a} [13.6-25.4]	12.0±0.7^{a} [1.3-25.4]	5.0±0.4^{b} [0.0-25.8]	10.0±0.8^{a} [0.6-25.4]	0.000	47.6***
K^{+} ppm	-0.26***	-0.12*	979.0±83.9^{ab} [479.0-1284.0]	1126.0±81.0^{b} [346.0-4022.0]	861.7±24.8^{ac} [261.0-4022.0]	1128.5±56.8^{b} [479.0-1650.0]	0.000	10.1***
Na^{+} ppm	-0.28***	-0.22***	1057.4±219.4^{a} [177.6-1869.3]	752.1±83.3^{a} [98.5-4019.2]	325.5±27.8^{c} [98.5-4019.0]	422.8±42.9^{c} [177.6-1532.7]	0.000	29.3***
Ca^{2+} ppm	-0.41***	-0.18**	13450.2±3392.0^{a} [6218.0-43520.0]	12274.5±1318.7^{a} [3832.0-43520.0]	7049.1±172.0^{b} [2564.0-14704.0]	10291.0±290.0^{a} [4056.0-14704.0]	0.000	29.4***
Fe^{2+} ppm	0.31***	0.14**	199.5±38.8^{a} [9.3-318.8]	51.7±9.0^{b} [7.8-318.8]	108.3±6.5^{c} [6.4-772.0]	57.3±9.3^{b} [13.1-318.8]	0.000	17.8***
EC mmhos/cm	-0.21***	-0.14**	2.9±1.0^{ab} [1.2-11.7]	6.0±1.6^{a} [0.4-58.0]	1.3±0.5^{b} [0.4-4.3]	1.5±0.1^{b} [0.5-3.5]	0.000	21.9***
pH	-0.46***	-0.19***	7.3±0.1^{a} [6.7-7.6]	7.4±0.0^{a} [6.7-8.0]	6.7±0.0^{b} [4.7-8.0]	7.3±0.0^{a} [6.1-7.7]	0.000	40.9***
Life forms								
Chamaephyte (%)	-0.19***	-0.23***	1.1±1.1^{a} [0.0-11.1]	2.8±0.5^{b} [0.0-11.1]	0.2±0.1^{a} [0.0-5.9]	0.4±0.3^{a} [0.0-10.53]	0.000	33.5***
Geophyte (%)	0.39***	0.16**	29.4±1.4 ^{a} [23.8-40.0]	30.9±1.4^{a} [7.1-56.3]	41.9±0.6^{b} [15.4-64.7]	30.3±1.3^{a} [7.1-50.0]	0.000	34.7***
Helophyte (%)	-0.43***	-0.13*	32.7±3.1 ^{a} [16.7-47.6]	22.5±1.1^{b} [6.3-47.6]	15.8±0.4^{c} [4.4-47.6]	24.0±1.5^{b} [12.2-50.0]	0.000	36.7***
Hemicryptophyt (%)	0.37***	0.12*	17.0±1.7 ^{a} [11.1-25.0]	26.9±1.2^{b} [11.1-42.9]	30.7±0.5^{c} [0.0-50.0]	22.6±1.1^{a} [8.3-42.9]	0.000	22.3***
Hydrophyte (%)	-0.39***	0.05	3.6±0.8 ^{ab} [0.0-9.4]	2.2±0.5^{b} [.0.-17.7]	2.0±0.3^{b} [0.0-15.8]	9.6±0.9^{a} [0.0-25.0]	0.000	39.2***
Therophyte (%)	-0.15**	-0.1	15.7±3.6 ^{a} [0.0-27.8]	13.2±1.3^{a} [0.0-33.3]	9.1±0.3^{a} [0.0-26.1]	13.2±1.3^{a} [0.033.3]	0.043	2.7*
Phanerophyte (%)	-0.1	-0.21***	0.6±0.6 ^{ab} [0.0-5.6]	1.5±0.3^{a} [0.0-7.7]	0.3±0.1^{b} [0.0-10.0]	0.0±0.0^{b} [0.0-0.0]	0.000	16.0***
Phytogeographic elements								
PE_1 "Broadly pluriregional" (%)	-0.35***	-0.24***	59.7±1.9 ^{a} [44.4-63.3]	49.6±1.2^{b} [28.6-71.4]	41.2±0.4^{c} [26.1-62.5]	45.8±1.4^{d} [28.6-71.4]	0.000	36.0***
PE_2 "Narrowly pluriregional" (%)	0.28***	0.22***	0.0±0.0 ^{a} [0.0-0.0]	0.9±0.1^{ab} [0.0-3.8]	2.0±0.2^{c} [0.0-50.0]	1.3±0.1^{bc} [0.0-3.8]	0.000	16.1***
PE_3 "Irano-Turanian" (%)	0.45***	0.10*	8.8±1.1 ^{a} [6.7-16.7]	13.9±1.0^{a} [0.0-38.1]	23.3±0.5^{b} [0.0-43.6]	15.8±0.9^{a} [0.0-27.7]	0.000	38.6***
PE_4 "Endemic" (%)	031***	0.21***	0.0±0.0 ^{a} [0.0-0.0]	1.9±0.3^{ac} [0.0-14.3]	4.5±0.2^{b} [0.0-18.2]	2.8±0.4^{c} [0.0-14.3]	0.000	18.1***

altitudes, whilst towards higher altitudes, vegetation group C has endemic and other geographically-restricted taxa.

Environmental gradients across the main vegetation groups

Classification and ordination techniques are often used to define plant communities and to identify the underlying environmental gradients (Kent and Ballard 1988). In the current study, the different types of wetland vegetation assessed by both methods indicated relatively similar positions. The wide range of wetland habitats, bed types and their possible combination produce a large variety of wetland vegetation features. This potential variability is actually limited because there is always one environmental factor dominating the remaining ones (Sterling 1996).

Generally, the vegetation differs substantially from one another in both species composition and environmental characteristics. These patterns suggest differences in their origins and history. Environmental condition in the Alborz Mountain wetlands left many places where aquatic flora could survive: 1) slightly acidic and low calcareous vegetation at high altitudes (group C); 2) slightly basic and moderately calcareous rich vegetation at middle altitudes. This vegetation subdivided to: a) saline vegetation (group B); b) non saline vegetation (group D); 3) slightly basic and calcareous rich vegetation in lower altitudes (group A).

The first DCA axis is related to the separation of total vegetation based on altitude and soil pH, i.e. acidic soil in higher altitude (wet meadow vegetation or group C) to alkaline soil in the lower altitude (river bank and lakeshore vegetation or groups A and D respectively). The results indicate that environmental variables have different effects and roles in our studied area, as some of these, are main factors such as altitude and soil pH.

In line with our hypothesis, altitude as the most important factor is responsible in case of vegetation differentiation. The influence of altitude on wetland vegetation has been also reported (Sterling 1996; Naqinezhad et al. 2009). This ecological factor is changed significantly between all vegetation groups (Table 3). Here like other areas, soil pH is considered to be another determinant of vegetation diversity in many habitats (e.g. Chytrý et al. 2003; Petraglia and Tomaselli 2003). A gradient from base-poor to base-rich condition is also shown due to variation in soil calcium content from the wet meadow habitats to the lakeshore and river bank vegetation groups. This poor-rich gradient is one of the main gradients in wetland habitats (Hájek et al 2002; Sjors 1952; Waughmann 1980; Gerdol 1995; Wheeler and Shaw, 1995)

Vegetation group C is more cryophilic and acidophilic than the others. This vegetation group is mainly located in the organic matter-rich soils in the higher altitudes. The increasing of soil OM can be interpreted by climate changing i.e. decreasing of annual mean temperature in the higher altitudes (Ganuza and Almendros 2003; Dai and Huang 2006). In this situation, soil pH is decreased because of accumulation of organic substance especially humic acids. The negative correlation between soil pH and accumulation of organic matter is also consistent with the results of Vitt (2000), Tahvanainen et al. (2002) and Hájek et al. (2005). In an investigation of Welsh wet meadow soils, the concentrations of Fe^{2+} and organic matter were positively correlated with acidity in the soil (Blackstock et al. 1998).

Due to mineral accumulation especially in the lower altitude habitats, they have high value of EC and pH, and related vegetation groups are more saline. Therefore halophyte species such as *Phragmites australis, Schoenoplectus lacustris* and *S. mucronatus* frequently occur in these vegetation groups. The high amount of salinity restricts plant growth and thus the species richness is indeed the least among the four vegetation groups.

Vegetation groups A and D have fine-textured soils which are associated with richness of some elements such as Ca^{2+}, K^+ and as a result, higher conductivity in the soil. The low amount of K^+ in the wet meadow habitats can be explained by the high amount of organic matter, as found by Blackstock et al. (1998). The positive relationships between the K^+ concentration and proportion of clay and silt in the soil was also known, since the fine-texture soils can prevent K^+ leaching from the soil (Mengel 1982). The concentration of these elements decreases towards the wet meadow vegetation group (group C) as found by other authors in ombrogenous wetlands (Bootsma and Wassen 1996).

Conclusion and conservation notes

Iran is located in the world arid belt. The country possessing 22 Ramsar international wetlands plays important role in the conservation of fresh water habitats and especially aquatic wetlands. Although total surface of the Alborz wetlands are not extensive, they represent four large types of vegetation and ecological environments. It demonstrates the importance of a wetland ecosystem in regional ecosystem equilibrium. This paper clearly shows that many wetlands of high value in terms of floristic biodiversity, scientific importance and biodiversity conservation occur in the southern slope of Alborz Mountains. The wetlands in arid or semiarid mountains are from conservational importance in case of biodiversity, endemic species and floristic-environmental interactions. Different environmental factors such as altitude, physico-chemical properties of soil lead to differentiate floristic composition between the wetland vegetation groups. The upper mountain wetlands are particularly important and mostly characterized with wet meadow vegetation; they contain more endemics and are more species-rich. The supplementary physic-chemical properties of soil, species life-form and phytogeographical measurements are also correlated with altitude and vegetation groups.

High mountain wetland vegetations have been less affected by human in comparison to the lowlands, as the latter envisages harsh conditions, human settlements and intensive agricultural activities. A great number of wetland habitats are still under the threat of damage and destruction by making of reservoirs, abstraction of groundwater for drinking water supply and intensive overgrazing. Their protection would guarantee a survival of many unique plant populations and legal protection should therefore be prioritized.

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LITERATURE CITED

ALLISON L.E., MOODE C.D. 1965. Methods of soil analysis. Part 2. Agronomy Series, No. 9, American Society of Agronomy, Wisconsin Series, 1379 pp.

BLACKSTOCK T.H., STEVENS D.P., STEVENS P.A., MOCKRIDGE C.P., YEO M.J.M. 1998. Edaphic relationships among Cirsio-Molinietum and Related wet grassland communities in lowland Wales. J. Veg. Sci. 9:431-444.

BOOTSMA M.C., WASSEN M.J. 1996. Environmental conditions and fen vegetation in three lowland mires. Vegetatio 127: 173-189.

BOUYOUCUS G.J. 1951. A recalibration of the hydrometer for making mechanical analysis of soils. Agron. J. 43:434-438.

BRAUN-BLANQUET J. 1964. Pflanzensoziologie: Grundzüge der Vegetationskunde. 3. neu bearb. Aufl. Springer-Verlag, Wien, 866 pp.

CHYTRÝ M., TICHÝ L., ROLEČEK J. 2003. Local and regional patterns of species richness in Central European vegetation types along the pH/Calcium gradient. Folia Geobot. 38: 429-442.

DAHLQUIST R.L., KNOLL J.W. 1978. Inductively Coupled Plasma-Atomic Emission Spectrometry: Analysis of biological materials and soils for major trace, and ultra-trace elements. Appl. Spectrosco. 32: 1-30.

DAI W., HUANG Y. 2006. Relation of soil organic matter concentration to climate and altitude in zonal soils of China. Catena 65: 87-94.

GANUZA A., ALMENDROS G. 2003. Organic carbon storage in soils of the Basque Country (Spain): the effect of climate, vegetation type and edaphic variables. Biology and Fertility of Soils 37:154-162.

GERDOL R. 1995. Community and species-performance patterns along alpine poor-rich mire gradient. J. Veg. Sci. 6 (2): 175--182.

GERDOL, R., TOMASELLI, M. 1993. The vegetation of wetlands in the northern Apennines (Italy). Phytocoenologia 21: 421-469.

HÁJEK M., HÁJKOVA P., APOSTOLOVA I., HORSÁK M., PLÁŠEK V., SHAW B., LAZAROVA M. 2009. Disjunct Occurrences of Plant Species in the Refugial Mires of Bulgaria. Folia Geobot. 44:365-386

HÁJEK M., HÁJKOVA P., SOPOTLIEVA D., APOSTOLOVA I., VELEV N. 2008. The Balkan wet grassland vegetation: a prerequisite to better understanding of European habitat diversity. Plant Ecol. 195: 197-213.

HÁJEK M., HEKERA P., HÁJKOVA P. 2002. Spring fen vegetation and water chemistry in the Western Carpathian flysch zone. Folia Geobot. 37: 205-224.

HÁJEK M., TZONEV R.T., HÁJKOVA P., GANEVA A.S., APOSTOLOVA I. 2005. Plant communities of subalpine mires and springs in the Vitosha Mt. Phytol. Balcan. 11: 193-205.

HÁJKOVA P., HÁJEK M., APOSTOLOVA I. 2006. Diversity of wetland vegetation in the Bulgarian high mountains, main gradients and context-dependence of the pH role. Plant Ecol. 184: 111-130.

HILL M.O. 1979. TWINSPAN – a FORTRAN program for arranging multivariate data in an ordered two way table by classification of individuals and attributes. Section of Ecology and Systematics. Cornell University, Ithaca, NY.

JAFARI S. M., AKHANI H. 2008. Plants of Jahan Nama Protected Area, Golestan Province, N. Iran. Pak. J. Bot. 40: 1533--1554.

KHALILI A. 1973. Precipitation patterns of Central Alburz. Arch. Met. Geoph. Biokl. Ser. B 21:215-232.

KENT M., BALLARD J. 1988. Trends and problems in the application of classification and ordination methods in plant ecology. Vegetatio 78: 109-124.

KESSLER M. 2000. Elevational gradients in species richness and endemism of selected plant groups in the central Bolivian Andes. Plant Ecol. 149: 181-193.

KLEIN J.C. 2001. La végétation altitudinale de L'Alborez Central (Iran): entre les régions irano-touranienne et euro-sibérienne. Téhéran: Institut Français de Recherche en Iran.

KLEIN J.C., LACOSTE A. 1995. Les pozzines à *Carex orbicularis* Boott subsp. *kotschyana* de l'Alborz central (Iran): groupement à la charnière des régions euro-sibérienne et irano-touranienne. Ecologia Mediterranea 12: 75-86.

KLIMEŠ L. 2003. Life-forms and clonality of vascular plants along an altitudinal gradient in E Ladakh (NW Himalayas). Basic Appl. Ecol. 4: 317-328.

LEPŠ J., ŠMILAUER P. 2003. Multivariate analysis of ecological data using CANOCO. Cambridge University Press, 269 pp.

McCUNE B., MEFFORD M.J. 1999. PC-ORD. Multivariate analysis of ecological data. Version 4. MjM Software Design, Gleneden Beach, Oregon, USA. 237 pp.

MENGEL K. 1982. Dynamics and availability of major nutrients in soils. Adv. Soil Sci. 2: 65-131.

NAQINEZHAD A., JALILI A., ATTAR F., GHAHREMAN A., WHEELER B.D., HODGSON J.G., SHAW S.C., MAASSOUMI A. 2009. Floristic characteristics of the wetland sites on dry southern slopes of the Alborz Mts., N. Iran: The role of altitude in floristic composition. Flora 204: 254-269.

NAZARIAN H., GHAHREMAN A., ATRI M., ASSADI M., 2004. Ecological factors affecting 168 parts of vegetation in north Iran (Elika and Duna Watersheds) by employing ecophytosociological method. Pak. J. Bot. 36:41-64.

NELSON D.W., SOMMERS L.E. 1996. Total carbon, organic carbon and organic matter. In: Page A.L. et al., Methods of Soil Analysis, Part 2, 2nd ed. Agronomy 9:961-1010. Am. Soc. of Agron., Inc. Madison, WI.

NOROOZI J., AKHANI H., BRECKLE S.W. 2008. Biodiversity and phytogeography of the alpine flora of Iran. Biodivers. Coserv. 17: 493-521.

ODLAND A. 2009. Interpretation of altitudinal gradients in South Central Norway based on vascular plants as environmental indicators. Ecol. Indic. 9: 409-421.

PAGE A.L. (ed.). 1982. Methods of soil analysis. Part 2. Chemical and microbiological properties, 2nd Ed., ASA, SSA, Madison, WI 53711.

PETRAGLIA A., TOMASELLI M. 2003. Ecological profiles of wetland plant species in the northern Apennines (N. Italy). J. Limnol. 62: 71-78.

PINTO J.R.R., OLIVEIRA-FILHO A.T., HAY J.D.V. 2006. Influence of soil and topography on the composition of a tree community in a Central Brazilian valley forest. Edinb. J. Bot. 62: 69-90.

RAUNKIAER C. 1934. The life forms of plants and statistical plant geography. Oxford, Charendon Press.

RECHINGER K.H. (ed.). 1963-2005. Flora Iranica. Vols. 1-173, Akademische Druck-U., Verlagsanstalt, Graz.

ROLON A.S., MALTCHIK L. 2006. Environmental factors as predictors of aquatic macrophyte richness and composition in wetlands of southern Brazil. Hydrobiologia 556: 221-231.

SJÖRS H. 1952. On the relation between vegetation and electrolytes in north Swedish Mire waters. J. Ecol. 90:650-657.

STERLING A. 1996. Los sotos, refugio de vida Silvestre. Ministerio de Agricultura Pesca y Alimentacion, Madrid.

STÖKLIN J. 1974. Northern Iran: Alborz Mountains. Geological Society, London, Special Publications. 4: 213-234.

TAHVANAINEN T., SALLANTAUS T., HEIKKIL A.R., TOLONEN K. 2002. Spatial variation of mire surface water chemistry and vegetation in north-eastern Finland. Ann. Bot. Fenn. 39: 235-251.

TAKHTAJAN A. 1986. Floristic regions of the world. University of California Press, Berkley, Los Angeles, London.

TER BRAAK C.J.F., ŠMILAUER P. 2002. CANOCO reference manual and CanoDraw for windows User's Guide: Software for canonical community ordination (version 4.5). Microcomputer Power (Ithaca NY, USA), 500 pp.

VICTORIA W. 2009. Eurosiberian meadows at their southern edge: patterns and phytogeography in the NW Tien Shan. J. Veg. Sci. 20: 199-208.

VITT D.H. 2000. Peatlands: ecosystems dominated by bryophytes. In: Shaw A.J. and Goffinet B. (ed.), Bryophyte biology, Cambridge University Press, Cambridge, pp: 312-343

WAUGHMAN G.J. 1980. Chemical aspects of the ecology of some south German peatlands. J. Ecol. 68:1025-1046

WHEELER B.D., SHAW S.C. 1995. A focus on fens-controls on the composition of fen vegetation in relation to restoration. 49--72. in Wheeler B.D., Shaw S.C., Fojt W.J., Robertson R.A. (eds), Restoration of Temperate Wetlands, Wiley & Sons, Chichester.

ZOHARY M. 1973. Geobotanical foundations of the Middle East. 2 vols. Fischer Verlag, Stuttgart, Amsterdam.