

SOIL PROPERTY VARIATIONS IN RELATION TO PLANT COMMUNITY AND ALTITUDINAL ZONE IN THE RANGELANDS OF EPIRUS, GREECE

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Abstract

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Epirus is a mountainous area in northwest Greece. Most of the rangelands extended there are overgrazed and eroded. This study was performed in order to assess soil property variations along with the dominant plant communities, the altitudinal zone and their interaction in the Preveza Prefecture grasslands in Epirus. Forty-eight field sites, with a west-southwest aspect divided into three different altitudinal zones, representing the typical rangeland conditions of this area were selected. These rangelands, based on the dominant species, were grouped into six plant communities (*Bromus – Hordeum*, *Festuca – Lotus*, *Asphodelus*, *Pteridium*, *Phlomis*, and *Quercus*). Therefore, four representative soil samples from the surface layer were collected from each plant community area for the purposes of the experiment. Soil texture, organic matter, electrical conductivity, pH, active Ca, NO₃-N, available P, exchangeable K, Cd, and Pb were analyzed and estimated. Soil texture showed significant differences among altitudinal zones, while soil organic matter, electrical conductivity, pH, active Ca, NO₃-N, available P, exchangeable K, Cd, and Pb presented significant differences among plant communities. The results of this study showed that the soil's physical and chemical properties are significantly affected by the altitudinal zone, although plant communities significantly affected mostly the soil's chemical properties, indicating that each plant community created its own soil micro environmental conditions.

Key words: soil properties, altitudinal zone, plant community

Introduction

Soil is a primary factor indicating the potential of an area for rangeland production within a particular climate (Holechek et al., 1995). In the Medi-

terranean basin, ecosystems are characterized as highly heterogeneous in time and space (Stamou, 1998). The inherent spatial heterogeneity of Mediterranean soils is enhanced by the coexistence of plants with different life cycles, such as evergreen

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sclerophyllous and seasonally dimorphic shrubs, and also by anthropogenic impacts (Quezel and Barbero, 1982). Plant life cycle is a factor introducing differences in soil properties; therefore, soil samples collected from the sites with dimorphic species share common soil properties, whereas sites with different evergreen species showed soil properties distinct for each specie (Monokrousos et al., 2004).

The temporal and spatial variations in soil properties developed a significant relation between biotic and abiotic factors such as topographic aspect, landscape position, slope degree, microclimate differentiations, lithological origins, and vegetation communities (Critchley et al., 2002; Oztas et al., 2003; Yimer et al., 2006; Pueyo and Alados, 2007; Gong et al., 2008; Whitford et al., 2008; Oyonarte et al., 2008).

In Epirus, the rangelands are extended mainly from mountainous to semi-mountainous areas. A previous study (Roukos et al., 2006) showed that these rangelands present a serious degradation problem as a result of overgrazing, a typical phenomenon in communal ownership. However, there has been no extensive study on this complex topography concerning the interaction among altitudinal zone, plant community, and soil properties. Soil is a dynamic but sensitive layer presenting constant chemical, physical, and biological activities; therefore, it is essential to know, understand, and adopt an effective system for its better conservation and manipulation in the Preveza Prefecture rangelands.

The aim of this study was to determine the possible interactions of physical and chemical soil properties with altitudinal zone and plant communities in the rangelands of the Preveza Prefecture.

Materials and Methods

Studied Area

This study was carried out in the Preveza Prefecture in Epirus, north-western Greece. The area

is distinguished for the diversity its landscape and its natural alternations. On this complex landscape are extended approximately 47700 ha of natural pasturelands where more than 10000 heads of cattle, 152000 heads of sheep, and 56.000 heads of goats are maintained (Roukos et al., 2006).

Geologically, the area belongs to the Ionian geotectonic zone, with basic substrate such as dolomites, Vigla, limestones, and flysch (I. G. M. E., 2006). Long term records of the climate of the studied area where obtained from Soulis (1994). Accordingly, the climate is typical Mediterranean, characterized by rainy cold winters and dry warm summers; with a mean monthly temperature ranging between 8.7°C and 26.4°C in January and July, respectively, and a mean annual rainfall reaching up 1344.9 mm (SD = ± 286.6) for the period of 1951-2001.

Sample collection

For the purposes of the experiment, 48 sites with a west south-west aspect, representing the typical rangeland conditions in the Preveza Prefecture, were selected (Figure 1). It is important to note that the studied sites are located on gentle and steep slopes; therefore, they have never been cultivated before. Three altitudinal zones, based on the above sea altitude, were differentiated as given below: upper (1001 - 1430 m), middle (501 - 1000 m), and lower (0 - 500 m).

Greek rangelands are generally classified into four types (Papanastasis and Noitsakis, 1992): grasslands, phrygana, shrublands (brushlands), and forest grasslands. In our studied area, only forest grasslands were excluded and from the 48 sites; six plant communities were identified based on the dominant species, *Bromus - Hordeum*, *Festuca - Lotus*, *Asphodelus*, *Pteridium*, *Phlomis*, and *Quercus* (Table 1) (Papanastasis and Noitsakis 1992; Roukos 2004).

Forty-eight representative soil samples were collected from the surface layer (0 - 30 cm) in March 2008. Prior to soil physical and chemical analyses, all samples were air-dried at room temperature and passed through a 2 mm soil sieve.

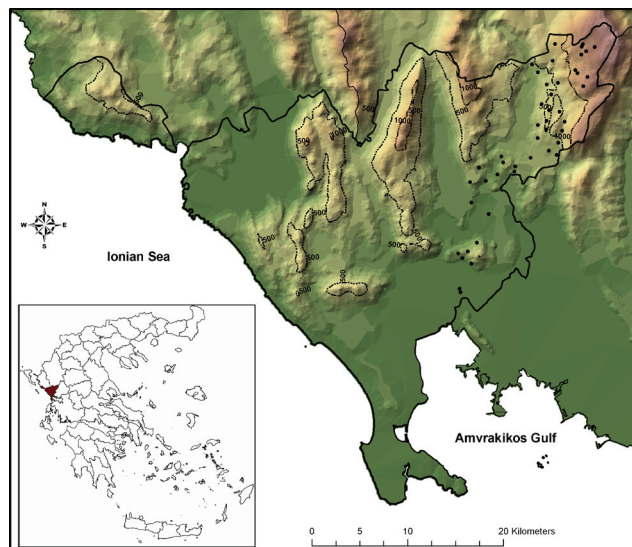


Fig. 1. Location of sampling sites of the study area

Table 1

Preveza sites: general characteristics

Range type	Altitudinal zone	Plant community (based on dominant species)	Abbreviation	Sites selected
Grassland	Lower – Middle	<i>Bromus squarrosus</i> L. - <i>Hordeum bulbosum</i> L. - <i>Anthyllis vulneraria</i> L. - <i>Trifolium repens</i> L.	<i>Bromus – Hordeum</i>	8
Grassland	Upper	<i>Festuca ovina</i> L. - <i>Lotus corniculatus</i> L. - <i>Stipa pulcherrima</i> K. Koch	<i>Festuca - Lotus</i>	4
Grassland	Lower	<i>Asphodelus aestivus</i> Brot.	<i>Asphodelus</i>	4
Grassland	Lower-Middle	<i>Pteridium aquilinum</i> (L.) Kuhn	<i>Pteridium</i>	8
Phrygana	Lower-Middle-Upper	<i>Phlomis fruticosa</i> L.	<i>Phlomis</i>	12
Shrubland	Lower-Middle-Upper	<i>Quercus coccifera</i> L. – <i>Phillyrea media</i> L. - <i>Arbutus unedo</i> L.	<i>Quercus</i>	12

Analytical Methods

Chemical analyses were performed in order to evaluate certain physical and chemical properties of the soil. Soil particle size distribution was determined with the hydrometer method (Gee and Or, 2002) and organic matter by the Walkley Black method (Nelson and Sommers, 1996); electrical conductivity (ds/m) was measured in a water suspension using a soil/solution ratio of 1/1 (Rhoades,

1996). The pH measurements were assessed in a water suspension using a soil/solution ratio of 1/2 (Thomas, 1996); active Ca (ppm) was determined with the use of ammonium oxalate (Loeppert and Suarez, 1996), and NO₃ in a 2M KCl extract (1:10 soil dry weight (d.w.): solution) through distillation and subsequent titration (Mulvaney, 1996). Available P (ppm) was evaluated with the Olsen method (Kuo, 1996), exchangeable K (ppm) with ammonium acetate (Helmke and Sparks, 1996), and lastly, Cd (ppm) and Pb (ppm) with the DTPA method (Amacher, 1996). All the results of these analyses were grouped for each plant community and altitudinal zone.

Statistical Analyses

A two way analysis of variance (ANOVA)

following the generated linear model (GLM) procedure of SPSS version 12.0.1 for Windows was performed to test statistical differences (Julie, 2001; SPSS Inc. 2003). The least square differences (LSD) method was used to determine significant differences between means when significant ANOVA results were observed. The Pearson's correlation was employed in order to examine the interrelationships among soil properties.

Results

Soil texture

The texture of the soil fractions varied significantly ($P < 0.05$) with altitudinal zone (Table 2). Sand and clay contents showed significant ($P < 0.01$) correlations with above sea altitude ($r = 0.786$ and $r = -0.766$, respectively). On the other hand, plant community did not significantly affect ($P > 0.05$) the texture of the soil fractions, except for sand fractions. However, the average proportion of the sand fractions was higher ($P < 0.05$) in the *Phlomis* plant community in relation to altitude (Figure 2), except for *Quercus* and *Pteridium* plant communities.

Soil chemical properties

Soil pH

The mean value of pH it was found to vary between 6.9 and 7.2 among altitudinal zones, with the higher value being recorded in the upper zone. The analysis of variance showed that plant communities significantly affected the soil's pH (Table 2), which ranged from 5.1 (*Pteridium*) in the lower zone to 7.6 (*Bromus* – *Hordeum*) in the middle zone (Figure 3). The soil's pH in the *Pteridium* plant community was significantly ($P < 0.05$) lower than in the other plant communities.

Soil organic matter

The results obtained showed that organic matter decreases with height in the following sequence:

Table 2

Results of two-way ANOVA showing the degrees of freedom, f-statistic and the significance of the effect of altitudinal zone and plant community on soil properties

Source of variation	d.f.	Sand		Silt		Clay	
		<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>
(a) Particle size							
Altitudinal Zone (Z)	2	54.056	0	5.65	0.006	31.125	0
Plant community (P)	5	2.488	0.045	1.465	0.22	0.94	0.464
Z x P	3	0.677	0.612	0.239	0.915	0.607	0.659
Source of variation	d.f.	pH		Organic Matter		EC	
		<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>
(b) Chemical properties							
Altitudinal Zone (Z)	2	0.953	0.393	21.345	0	4.812	0.013
Plant community (P)	5	16.002	0	12.426	0	18.891	0
Z x P	3	0.305	0.873	2.199	0.084	2.726	0.041
Source of variation	d.f.	Available P		NO ₃ -N		Active Ca	
		<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>
Altitudinal Zone (Z)	2	10.778	0	1.649	0.203	5.72	0.006
Plant community (P)	5	26.987	0	116.203	0	16.039	0
Z x P	3	7.768	0	4.867	0.002	1.379	0.256
Source of variation	d.f.	Exchangeable K		Cd		Pb	
		<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>
Altitudinal Zone (Z)	2	24.497	0	13.681	0	0.203	0.817
Plant community (P)	5	4.371	0.002	3.267	0.013	6.743	0
Z x P	3	3.456	0.015	2.673	0.044	1.125	0.356

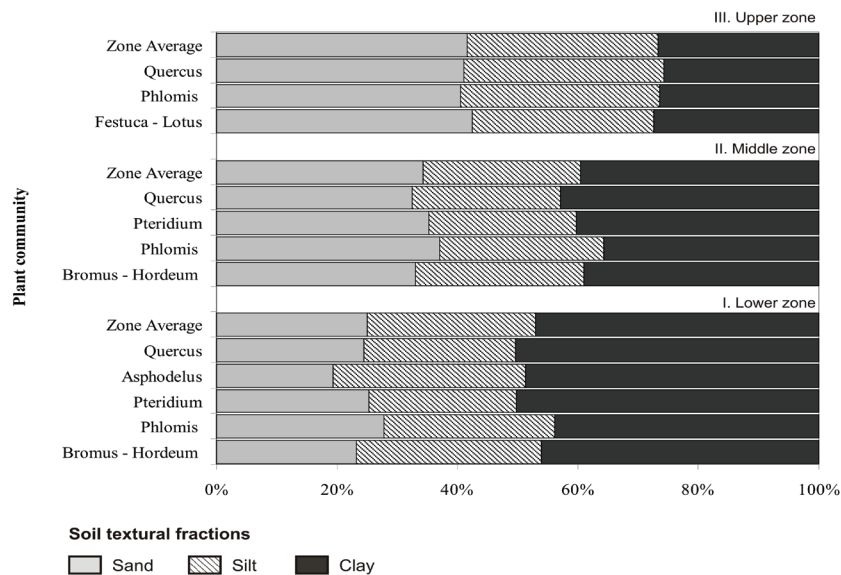


Fig. 2. Soil textural fractions in relation to altitudinal zone and plant community

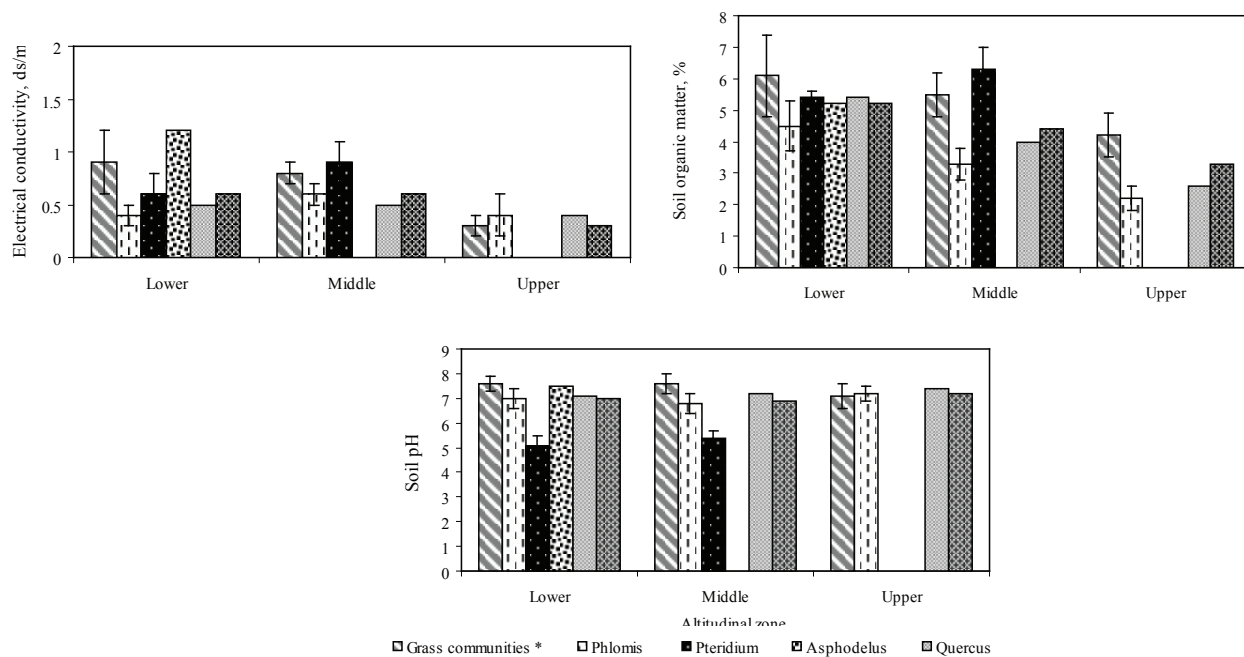


Fig. 3. Soil pH (1:2), organic matter and electrical conductivity in relation to altitudinal zones and plant communities (mean \pm S.E.)

lower zone > middle zone > upper zone, and demonstrates significant differences with altitudinal zone. On the average, organic matter varied from

3.3 to 5.2% in the upper and lower zones, respectively (Figure 3). The analysis of variance showed that organic matter content is influenced ($P <$

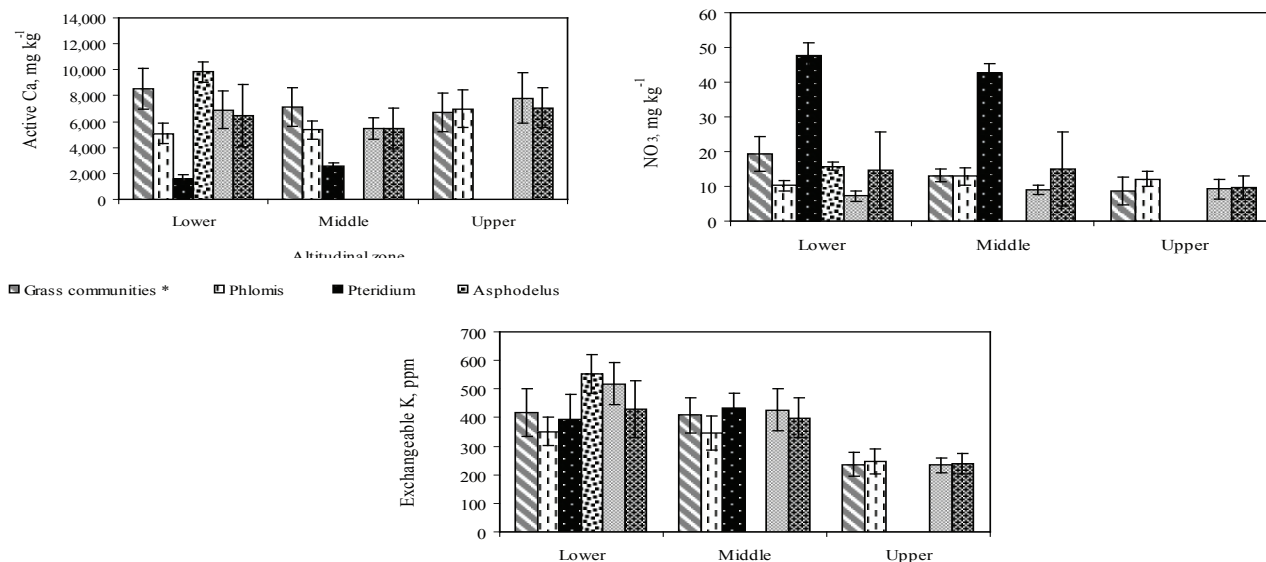


Fig. 4. Soil available phosphorus, active Ca, exchangeable K and NO₃-N content in relation to altitudinal zones and plant communities (mean ± S.E.)

0.001) by altitudinal zone and plant community.

The Pearson's correlation showed a significantly negative relation between organic matter and altitude ($r = -0.591$, $P < 0.01$), as well as between organic matter and sand content ($r = -0.551$, $P < 0.001$). In addition, organic matter is significantly related to both clay content ($r = 0.422$, $P < 0.001$) and the soil's electrical conductivity ($r = 0.541$, $P < 0.001$). The organic matter content of the soil surface layers is quite high in the *Pteridium* and *Asphodelus* plant communities, with a total average organic matter content of 5.5% and 5.2%, respectively (Figure 3).

Soil Electrical Conductivity (EC)

Soil EC significantly differed ($P < 0.05$) with both altitudinal zones and plant community types. The interaction effects between plant communities and altitudinal zones were also significant ($P = 0.003$) (Table 2). The mean values of EC (ds/m) range from 0.3 to 1.1 among plant communities and from 0.3 to 0.6 among altitudinal zones (Figure 3). The maximum mean values of EC are reported in the lower and middle zones, with an average of 0.6 dS / m, although in the upper zone the lowest value had an average of 0.4 dS / m. Therefore,

we conclude that there are statistically significant differences ($P < 0.001$) among the three altitudinal zones as far as EC values are concerned.

The Pearson's correlation demonstrated that the interaction between active Ca ($r = 0.308$, $P < 0.05$) and exchangeable K ($r = 0.586$, $P < 0.001$) can explain the relatively small EC variability in Preveza Prefecture soils. However, it was also shown that no significant ($P > 0.05$) relation existed between clay content and EC, although a correlation between sand content and EC was observed ($r = -0.337$, $P < 0.05$).

Available phosphorus, active Ca, exchangeable K, and NO₃-N content

From the results obtained, available P, active Ca, and exchangeable K presented significant variations with altitudinal zones and plant communities, while plant community also significantly affected NO₃-N content (Table 2, Figure 4).

Available P was significantly ($P < 0.05$) lower in the upper zone for all plant communities (Figure 4). In the lower zone, the availability of P in the *Asphodelus* plant community was significantly higher ($P < 0.05$) compared to other plant communities (Figure 2). Similarly, in the middle zone,

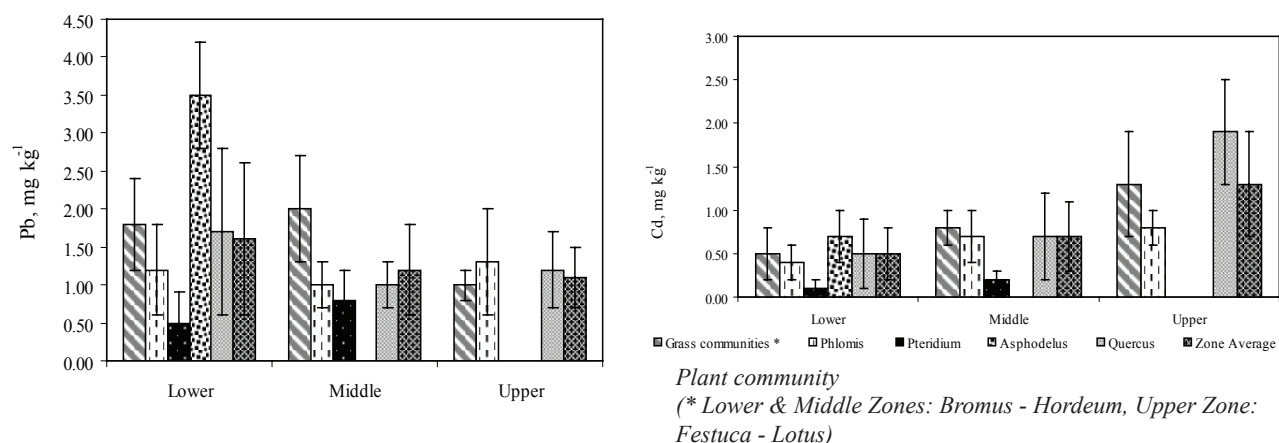


Fig. 5. Soil cadmium and lead content in relation to altitudinal zones and plant communities (mean \pm S. E.)

the *Pteridium* plant community showed significant phosphorus availability ($P < 0.05$).

The Pearson's correlation indicated that the available P and the exchangeable K content tended to decline with altitude ($r = -0.296$, $P < 0.05$ and $r = -0.673$, $P < 0.001$, respectively).

The active Ca content demonstrated no significant differences between the lower and the upper zones; in contrast to the other plant communities, active Ca was found to be significantly higher ($P > 0.05$) in the *Asphodelus* group.

The concentration of $\text{NO}_3\text{-N}$ significantly differed ($P < 0.001$) among plant communities (Table 2). Inorganic N concentrations were found to be significantly ($P < 0.05$) lower in the upper zone than in the other two zones, and thus were significantly ($P < 0.05$) higher in the *Pteridium* plant community compared to the other groups.

Cadmium and lead contents

The evaluation of cadmium and lead content showed that altitudinal zone and plant community had significant effects ($P < 0.05$) on cadmium content, while plant community significantly affected ($P < 0.05$) lead content (Table 2). The cadmium content varied from 0.1 to 1.3 mg kg⁻¹ among the altitudinal zones, with significantly higher values recorded in the upper zone ($P < 0.05$) (Figure 5). A similar correlation was observed for lead, with the content varying from 1.1 to 1.6 mg kg⁻¹

among altitudinal zones and the higher value also indicated in the upper zone.

Finally, the Pearson's correlation indicated the existence of significant interactions between altitudinal zones, and Cd and Pd content ($r = 0.583$, $P < 0.001$ and $r = -0.269$, $P < 0.05$, respectively).

Discussion

Considering all the results obtained from this experiment, we conclude that the high sand content in the upper zone indicates an erosion hazard that is more crucial than in the other altitudinal zones. This might be the result of an orographic effect (Souliis, 1994), explaining the fact that the studied area is characterized by a high mean annual precipitation that significantly increases with the above sea altitude. This leads to a partial runoff of fine soil fractions from the upper zone dominated with the *Festuca - Lotus* plant community, down the slopes, leaving behind only sand fractions. Therefore, an increased risk of erosion in the upper altitudinal zone as well as higher soil fertility in the lowlands are estimated, leaving plant species like *Phlomis* to grow and expand to soils characterized as sandy. This observation agrees with that of Debazac and Mavrommatis (1969), who reported that plant communities dominated by *Phlomis fruticosa* L. grow on dry, rocky, and friable soils.

The variations in soil chemical properties among plant communities are probably due to the differences in the nutrient cycle characteristics of contrasting vegetation (Dahlgren et al., 1997), or to the interspecific differences in soil acidity (e.g., organic acids), and Ca uptake and allocation (Finzi et al., 1998).

It has been shown that soil morphology, as much as continuous vegetation (Roukos 2004), drastically contributes to the erosion and water runoff that lead to gradual desertification (Papanastasis and Noitsakis, 1992). On the other hand, the high EC value observed in the *Asphodelus* community in the lower altitudinal zone is related to the high organic carbon concentration in the soil, thus showing its significant correlation with the production and preservation of organic matter (Yimer et al., 2006).

The relatively high levels of available P in the soil suggest that considerable amounts of P are present in forms suitable for plant uptake in the lower and middle zones, probably due to the mean annual precipitation causing increased mineralization and, consequently, biomass production. One possible explanation for this is that the soil chemical and environmental conditions interact with the plant community, stimulating decomposition, and the organic acids produced during decomposition may have increased the available P levels in the lower and middle zone soils relative to the upper zone soils (Iyamuremye and Dick, 1996). The low Ca concentration in the middle zone indicates that the extension of the erosion in the upper zone results in the leaching of the available Ca from the soil surface layer.

The overall mean active Ca content was higher than the exchangeable K content of soil for all plant communities and altitudinal zones. Although the nutrient cycle and the availability of K differ substantially among soils, all the plant communities seem to not be limited by P and K, which are known to limit plant growth. Soil N is a particularly important resource because its availability most often limits productivity and intensifies competi-

tion (competitive ability) among species in plant communities (Tilman and Wedin, 1991). It seems the *Festuca – Lotus* plant community absorbed more inorganic N from the soil solution than the other plant communities. This may be due to the fibrous root systems of the *Festuca – Lotus* plant community, which could have made them quite efficient at intercepting and absorbing $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ from the soil solution.

The variations in heavy metal content were related to environmental pollution, as these metals are released to the environment during human activities (Igwe et al., 2005). The soil cadmium content of the Preveza Prefecture rangelands is quite higher than the 0.2 mg kg^{-1} found by Roberts et al. (1994) in New Zealand rangeland soils. Since cadmium and lead uptake by forage plants are a cause for concern because the chemicals are potentially toxic when consumed at low concentrations (Codex Alimentarius Commission, 1999), further research on the heavy metal content of soils from the altitudinal zones and plant communities will be required to explain the differences observed.

In mountainous topography, significant variations in soil physical and chemical properties in relation to landscape position and plant community have been reported in numerous studies (Brubaker et al., 1993; Oztas et al., 2003; Noellemeyer et al., 2006; Yimer et al., 2006; Oyonarte et al., 2008). The results of this study concur with the findings of previous research.

Conclusion

The results of this study revealed that most of the Preveza Prefecture soil's physical and chemical properties exhibit variability in relation to altitudinal zones and plant communities. Altitudinal zone significantly affects most of the physical properties of the soil and some of its chemical properties, although plant community interferes with the soil's chemical properties. This leads to the conclusion that each plant community creates its own chemical micro environmental conditions,

which influence the nutrient cycles.

Further studies are required to completely understand the interactions among topographic attributes such as aspect and landscape positions, vegetation, and soil properties in order to create and manipulate certain management practices.

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