Environmental responses of vegetation composition along an altitudinal–climatic gradient of Western Crete, Greece

Dimitris Kazanis & Margarita Arianoutsou

Department of Ecology and Systematics, Faculty of Biology, University of Athens, GR–15784 Panepistimiopolis, Greece, e-mail: dkazanis@biol.uoa.gr (corresponding author)

Abstract. In the context of an intra-Mediterranean project aiming towards the study of the complex environmental degradation occurring in calcareous areas, the role of a number of environmental and anthropogenic factors on plant community composition along a climatic–altitudinal gradient of Western Crete was evaluated. Even though human activities have acted upon plant community composition, it was climate (as expressed via altitudinal changes) that was found to play the most important role in the distribution of plant species and vegetation units along the gradient. Leguminous flora was proved to act as an indicator of grazing impact on vegetation, either by being under- or over-represented.

Key words: altitudinal–climatic gradient, correspondence analysis, fire, grazing, legumes, Mediterranean ecosystems, species richness

Introduction

Despite the fact that they constitute only 1.2 % of the terrestrial ecosystems of the world, Mediterranean-type ecosystems rank second after the tropical forests for their biodiversity (Cowling & al. 1996). Although water deficit is the main stress for their biota, humans have affected and shaped Mediterranean-type plant communities since the Neolithic era, in particular at the Mediterranean Basin (Aschmann 1973). Their impact was a relatively slow and cumulative process of modifying natural ecosystems by means of cultivation, logging and grazing. However, after the Second World War major changes have been recorded at these ecosystems (Antrop 1993; Arianoutsou 2001). Extensive rural migration, agricultural intensification with new machinery, excess use of fertilizers, irrigation technology, international commerce and pressure for tourist development are among the major trigger factors of changes occurred in the traditional land use patterns. These changes have often resulted in land degradation and desertification (Fantechi & Margaris 1986).

Environmental Responses of the Mediterranean Ecosystems (ERMES) was the title of an EU project, aiming towards the study of the complex environmental degradation that is perceived to be occurring in limestone and marl areas near the Mediterranean Sea (Imeson & al. 1996). For the project purposes, an inter-Mediterranean gradient of regions of increasing aridity from west (Spain) to east (Greece and Israel) was established, including local climatic gradients per region.

In this context, one of the goals of the research, which took place at the Greek sites, was the evaluation of the role played by a number of environmental and anthropogenic factors on plant community composition along the particular climatic gradient (Western Crete) established.

Material and methods

Study sites

Crete is a mountainous island which presents an impressive variety of natural, semi-natural and cultural landscapes (Rackham & Moody 1996). Due to large topographical variation, the island has a wide range of climatic types, from sub-tropical to alpine. It was on the western part of the island that a climatic–altitudinal gradient of sites has been established, with the

altitude varying from 50 m to 1050 m a.s.l. The gradient consisted of seven sites found within the limits of Mediterranean climate, ranging from sub-humid to semi-arid conditions. All sites were situated on south-facing slopes overlying limestone rocks. The major disturbance agent acting upon those sites was livestock grazing, while fire had occasionally been interacting with it. Plant communities in all sites of lower altitude (50 m to 700 m) were dominated by seasonal dimorphic shrubs, such as *Sarcopoterium spinosum*, *Coridothymus capitatus*, and *Genista acanthoclada* (phryganic shrublands), while plant communities of upland sites were dominated by the evergreen sclerophyllous shrub *Quercus coccifera* (maquis shrublands).

Data collection

Patches with rather homogeneous vegetation cover were considered for sampling. At each patch a 2×25 m^2 plot has been established. All plant species growing within the plot have been recorded. Field campaign took place at three months intervals during the period between June 1996 and June 1997, so as to cover as much floristic elements as possible.

Data analysis

The ordination of the plots against the prevailing environmental and anthropogenic factors was performed with the application of CANOCO (version 4.0 for Windows software) for Canonical Correspondence Analysis (ter Braak 1987). The factors and the nature of their scaling are shown in Table 1.

Plant species nomenclature

Plant species nomenclature follows Turland & al. (1993).

Results

In total, 120 plant taxa of 38 families have been recorded. The higher species richness was recorded at the two sites of higher elevation (Fig. 1). The vast majority of the recorded taxa were herbaceous annuals. In terms of plant family spectrum, *Leguminosae* (22 taxa) and *Compositae* (14 taxa) were the families with the highest number of taxa. *Compositae* did not present any particular trend against altitude. This was not the case for *Leguminosae* that met their minimum richness in the lowland sites.

The results of the Canonical Correspondence Analysis (CCA) are shown in Table 2 and Fig. 2. The set of variables chosen explains 54.62 % of the species data variance (sum of all canonical eigenvalues vs. sum of all unconstrained eigenvalues). From the values of canonical coefficients against the Axes 1 and 2, it can be inferred that the ordination along the first axis is clearly shaped by the altitudinal gradient, while for the second axis 'grazing' is mainly to be accounted for the result.

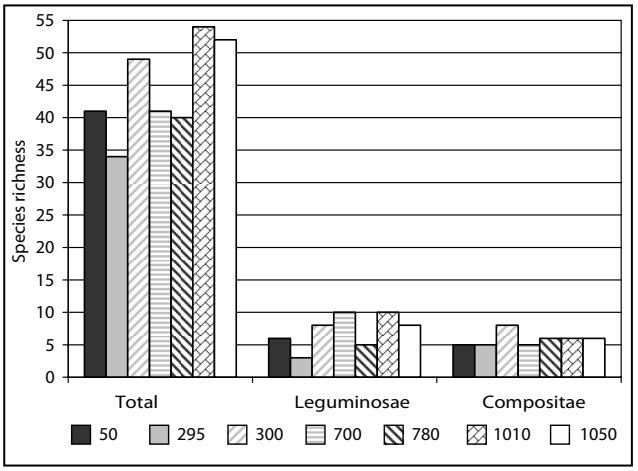

Fig. 1. Total plant species richness and number of recorded taxa of *Leguminosae* and *Compositae* families along the climatic–altitudinal gradient of Western Crete. Numbers in the legend refer to the altitude of the respective study site along the gradient.

Table 1. The variables included in the Canonical Correspondence Analysis (CCA) and the nature of their scaling.

Environmental variables	Code name	Nature of scale
Altitude	ALTITUDE	ordinal (m)
Grazing	GRAZING	nominal (0: only summer, 1: all year)
Fire incidents	FIRE	nominal (0: no, 1: yes)
Slope inclination	SLOPE	ordinal (°)

Table 2. The results of the Canonical Correspondence Analysis (CCA) as given by CANOCO 4.0 for Windows.

Axis variable	Axis 1	Axis 2	Total inertia
Eigenvalues	0.529	0.290	1.686
Species–environment correlations	0.967	0.913	
Cumulative percentage variance			
of species data	31.4	48.6	
of species–environment relations	42.3	65.6	
Canonical coefficients of variables			
Altitude	-1.230	-0.552	
Slope	0.278	0.356	
Grazing	0.166	-0.970	
Fire	0.156	0.767	
Sum of all unconstrained eigenvalues			1.686
Sum of all canonical eigenvalues			0.921

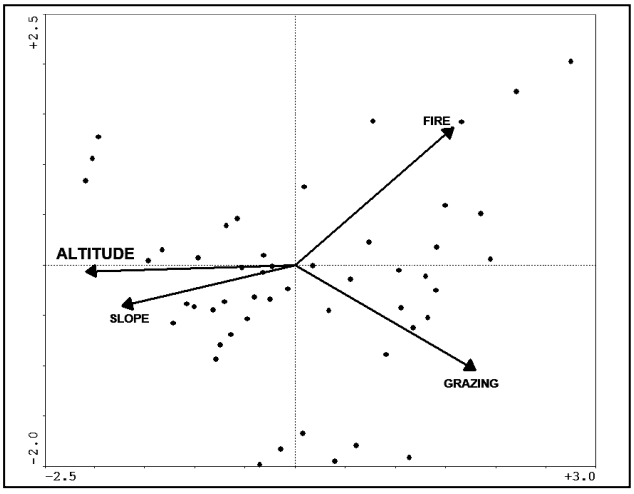

Fig. 2. Biplot ordination of plant species after Canonical Correspondence Analysis (CCA) of the vegetation composition data along the climatic–altitudinal gradient of Western Crete. Each circle represents one of the 120 recorded taxa.

Discussion

Changes in terms of vegetation composition along the gradient were found to be gradual, since the vast majority of taxa were present in more than one site. This seems to be a general observation in reports from other altitudinal gradients (Whittaker & Niering 1975; Auerbach & Schmida 1993). The gradual character of vegetation change lies on the fact that these changes are the result of plant species differential response to climatic variables. Floristic changes occur at the population level, through alterations of the relative abundance of the species, changing, in turn, community composition and structure (Miles 1981; McDonald & al. 1996).

After 'altitude', it was 'grazing' that was proved to play a major role in plant species ordination. 'Grazing' was included in the analysis in a nominal way, distinguishing sites grazed throughout the year from sites grazed only during the summer months, primarily due to the altitude (Papanastasis & al. 2003). The plant group mostly affected by grazing regime seems to be that of legumes. *Leguminosae* and *Compositae* were the two plant families presenting the highest number of species throughout the sites of the gradient. Still, the pattern of their richness versus altitude differed, probably due to different ecological attributes of their members (e.g., anemochory vs. zoochory, respectively [Kazanis & Arianoutsou 2004]). Species number of *Compositae* did not vary much along the gradient, whereas for legumes there was a trend of increasing species richness with altitude, in the contrary of what was expected, according to several data from Greece, reviewed by Arianoutsou & Thanos (1996).

Furthermore, Bergmeier & Matthäs (1995) reported that the altitudinal distribution of some species in Western Crete was broader than that reported by Turland & al. (1993). According to our data, there are 13 taxa that have been recorded from higher altitudes than reported by Turland & al. (1993). They are all herbs except of *Smilax aspera*, a woody climber. Three of them are legumes (*Trifolium angustifolium*, *Scorpiurus muricatus* and *Hippocrepis unisiliquosa*). This over-representation of legume species at sites of higher elevations might have been related to the fact that livestock animals are known to disperse legume seeds (Russi & al. 1992). The most prominent scenario is that seeds are dispersed by animals at the higher elevations during the summer months and onwards, they readily germinate and establish in wither months, when livestock animals are absent. On the contrary, legume species richness is under-represented in lowland sites because of their high palatability by livestock animals (Legg & al. 1998) that remain present all year long, preventing them from establishing adequately. This under-representation is more evident in recently burned sites, where legumes would have been expected to dominate (Arianoutsou & Thanos 1996).

Acknowledgements. This work was financially supported by the European Union, DG XII, Environment and Climate Program, under the project ERMES II, ENV4–CT95–0181. The authors would like also to thank Prof. V.P. Papanastasis for sharing with them his experience on the management and the land-use implications of Western Crete rangelands and Mr. S. Kyriakakis for his valuable help in the identification of some plant taxa.

References

Antrop, M. 1993. The transformation of the Mediterranean landscapes: an experience of 25 years of observations. – Landscape Urb. Planning, **24**: 3-13.

Arianoutsou, M. 2001. Landscape changes in Mediterranean ecosystems of Greece: implications for fire and biodiversity issues. – J. Medit. Ecol., **2**: 165-178.

Arianoutsou, M. & Thanos, C.A. 1996. Legumes in the Fire-Prone Mediterranean Regions: an Example From Greece. – Int. J. Wildland Fire, **6**(2): 77-82.

Aschmann, H. 1973. Man's impact on the several regions with Mediterranean climates. – In: **di Castri, F. & Mooney, H.A.** (eds), Mediterranean Type Ecosystems: Origin and Structure.

Ecological studies **7**, pp. 363-371. Springer-Verlag, Berlin, Heidelberg, New York.

Auerbach, M. & Schmida, A. 1993. Vegetation change along an altitudinal gradient on Mt Hermon, Israel; no evidence for discrete communities. – J. Ecol., **81**(1): 25-33.

Bergmeier, E. & Matthäs, U. 1995. Additions to the flora of W Crete. – Willdenowia, **25**(1): 81-98.

Cowling, R.M., Rundel, P.W., Lamont, B.B., Arroyo, M.K. & Arianoutsou, M. 1996. Plant diversity in mediterranean-climate regions. – Trends Ecol. Evol., **11**(9): 362-366.

Fantechi, R. & Margaris, N.S. (eds). 1986. Desertification in Europe. Commission of the European Communities. D. Reidel Publishing Co., Dordrecht, Boston, Lancaster & Tokyo.

Imeson, A.C., Allen, P., Arianoutsou, M., Calvo, A., Hill, J., Lavee, H., Mazzoleni, S. & Rubio, L.J. 1996. Projecting the impact of climate change and human activity on ecosystem degradation along climatic gradients (ERMES II). – In: Int. Conf. Medit. Desertification: Research Results and Policy Implications. Book of Abstracts: pp. 123-124. European Commission & Natl. Agric. Res. Found. Greece, Iraklio.

Kazanis, D & Arianoutsou, M. 2004. Long-term post-fire vegetation dynamics of *Pinus halepensis* forests of Central Greece: A functional group approach. – Pl. Ecol., **171**(1–2): 101-121.

Legg, C., Papanastasis, V.P., Heathfield, D., Arianoutsou, M., Kelly, A., Muetzelfeldt, R., & Mazzoleni, S. 1998. Modelling the impact of grazing on vegetation in the Mediterranean: The approach of the ModMED Project. – In: **Papanastasis, V.P. & Peter, D.** (eds), Ecological Basis of Livestock Grazing in Mediterranean Ecosystems. Pp. 189-199. European Commission, Luxembourg.

McDonald, D.J., Cowling, R.M. & Boucher, C. 1996. Vegetation-environment relationships on a species-rich coastal mountain range in the fynbos biome (South Africa). – Vegetatio, **123**(2): 165-182.

Miles, J. 1981. Problems in heathland and grassland dynamics. – Vegetatio, **46/47**(1): 61-74.

Papanastasis, V.P., Kyriakakis, S., Kazakis, G., Abid, M. & Doulis, A. 2003. Plant cover as a tool for monitoring desertification in mountain Mediterranean rangelands. – Managem. Environm. Qual., **14**(1): 69-81.

Rackham, O. & Moody, J. 1996. The making of the Cretan landscape. Manchester Univ. Press, Manchester.

Russi, L., Cocks, P.S. & Roberts, E.H. 1992. The fate of legume seeds eaten by sheep from a Mediterranean grassland. – J. Appl. Ecol., **29**(3): 772-778.

ter Braak, C.J.F. 1987. The analysis of vegetation-environment relationships by canonical correspondence analysis. – Vegetatio, **69**(1–3): 69-77.

Turland, N.J., Chilton, L., & Press, J.R. 1993. Flora of the Cretan Area: Annotated Checklist and Atlas. HMSO Publications, London.

Whittaker, R.H. & Niering, W.A. 1975. Vegetation of the Santa Catalina Mountains, Arizona: V. Biomass, production and diversity along the elevation gradient. – Ecology, **56**(4): 771-790.