JOURNAL OF ENVIRONMENTAL ENGINEERING
AND LANDSCAPE MANAGEMENT
2009
17(3): 154–163

# VEGETATION-ENVIRONMENT RELATIONSHIPS IN MEDITERRANEAN MOUNTAIN FORESTS ON LIMELESS BEDROCKS OF SOUTHERN ANATOLIA, TURKEY

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*Submitted 1 Dec. 2008; accepted 18 Mar. 2009*

**Abstract**. The forest resources of south Anatolia (Turkey) are characterized by degradation due to wood extraction, overgrazing and fire. In the context of forest restoration, afforestation, conservation, utilization and sustainability, vegetation-environment relationships need to be known. In the study, a data set from Mediterranean mountain forests on limeless bedrocks of southern Anatolia, consisting of species cover and environmental measures in 56 sample plots, was examined with canonical correspondence analysis. Results illustrated two vegetation gradients related to factor complexes of altitude-aspect and pH-total calcium carbonate. Axis I of the ordinate was strongly related to altitude, aspect, available water percentage of Bv, field capacity percentage of Bv, schistose quartzite and soil stoniness percentage. Axis II was strongly related to total lime percentage of Ah, total lime percentage of Bv, pH of Bv, schistose quartzite, pH of Cv, pH of Ah, slope degree, respectively. Species richness was correlated to pH-total calcium carbonate gradient whereas total vegetation cover was correlated to altitude-aspect gradient.

**Keywords:** Mediterranean forest, canonical correspondence analysis, vegetation pattern, environmental factors, diversity, *Pinus brutia*, *Pinus nigra.*

## 1. Introduction

In the context of forestry, limited studies have attempted on vegetation-environment relationships in Turkey. The first study as a PhD thesis, ended in 1971 and pressed in 1980, carried out by Kantarci (Kantarci 1980). There are next studies belonging to Kantarci carried on in different regions of Turkey (Kantarci 1974, 1975, 1979, 1991, 1995, 1998). Besides, Cepel (1978), Ayberk (1987) and Altun *et al*. (2002) investigated the same topic. In particular, out of these studies, the study carried out by Kantarci (1991) entitled "Regional Site Classification of Mediterranean region" attracted much attention by foresters. Because of the Turkey's ecosystems, Mediterranean forests have very important position, not only because of their species diversity but also because of their composition and complex structure. One of the components of this complexity is the heterogeneity of habitats which influences the spatial distribution of plant species. Spatial heterogeneity in the physical environment is an important factor contributing to the commonly high plant species diversity of Mediterranean forests, as variation in resource availability.

The study carried out by Kantarci (1991) about determination of vegetation-environment relationships in Mediterranean region didn't include the information in details in each subregion or district. Therefore, there was a need of much more detailed investigations in each subregion and district of Mediterranean region. Two PhD theses were carried out under control of Dr. M. Dogan Kantarci because of this reason. One is entitled "Forest site properties and classification in Beysehir Watershed" (Ozkan 2003), the other is entitled "Forest site properties and classification in Egirdir watershed" (Karatepe 2003). The last study on vegetation-environment relationships was carried out in Aglasun district from Mediterranean region (Fontaine *et al.* 2007).

However, the studies are equal to a very small part of Mediterranean region. There is still a need of much more studies.

Buldan district is located in Mediterranean region. The district has been the theatre of intense human activity for hundreds years for fuel wood, timber and livestock grazing. This long human interference with the natural ecosystem has led to a significant reduction of forest cover, while about half of the remaining forest can be considered degraded and unproductive (Ozkan 2006a).

Therefore, Vegetation-environment relationships in Buldan district will obtain not only more detailed information about Mediterranean ecosystems but also fundamental information support in terms of forestry management and applications including restoration, afforestation, conservation, utilization and sustainability in Buldan district. At the same time, owing to getting information on the vegetation-environment relationships, significant contributions will be obtained intended for regulation and restoration of hydrological regime (Okoński 2007; Povilaitis and Querner 2008), development of tourism (Burinskiene and Rudzkiene 2008), and understanding to the ecological properties for making management plans of meadows indirectly (Sendžikaitė and Pakalnis 2006).


ISSN 1648–6897 print / ISSN 1822-4199 online
DOI: 10.3846/1648-6897.2009.17.154-163

## 2. Material and Method

### 2.1. Site description

The study area (190 000 km$^2$) was the Buldan forest district (644 000–4 216 000 N and 663 000–4 206 000 E according to UTM coordinate system, 400–1400 m above the sea level) in southern Anatolia. A cool and sub-humid Mediterranean climate with pronounced winter precipitation and summer drought predominates (Ozkan *et al.* 2006). From 1980 to 1995 the mean monthly temperature at Buldan (610 m above the sea level) ranged from 7.48 °C (January) and 33.2 °C and the mean annual precipitation approximates 650 mm year-1 (DMI 2003). There are different parent materials except for limestone which is the most widespread in Mediterranean region. These are Precambrian aged gneiss; Miosen aged granite and Paleozoic schistose quartzite. Out of them, gneiss is the predominating parent material in Buldan district. Besides, Pliocene aged sandstone clay stone deposits and Quaternary alluvium deposits are present in the district (Senol 2006).

Soil depth, moisture content and stoniness vary with parent material and topography (Ozkan *et al.* 2006). Most soils can be classified as leptosols, regosols or cambisols depending on shallowness and stoniness (FAO *et al.* 1998).

The study area is covered about 40% by Mediterranean mountain forests mainly composed of *Pinus brutia* (Brutian pine), *Pinus nigra* (Crimean pine) and *Quercus* spp. The remainder of the area consists of agricultural land. The area has a long history of human settlement and forest utilization, including a high grazing pressure (Ozkan 2006a).

### 2.2. Data set

Fifty-six plots, 20 X 20 m in size, were sampled in the Buldan district in July–September 2006. Vegetation and environmental measurements were surveyed in all the 56 plots. Cover estimates were made for all vascular species using Braun-Blanquette scale in each plot. One hundred and eight species were recorded. Fifty-two very rare species (less than 3 occurrences throughout the data set) were removed to reduce bias in the analysis. The remaining 56 species were taken for the analysis. The species were given with codes of them in Table 1. Braun Blanquette scores were transformed to relative cover (r: 0.01; +: 0.02; 1: 0.04; 2: 0.15; 3: 0.375; 4: 0.625; 5: 0.875) (Fontaine *et al.* 2007). Richness (the number of plant species), woody cover (trees and shrubs greater than 1.5 m tall) were recorded. Total vegetation cover was calculated as the sum of the cover of all the species regardless of the overlap (Jeglum and He 1995).

Forty-seven environmental variables were sampled on the plots and coded (Table 2). Sample plots were coded from sample plot 1 to sample plot 56 as S1 to S56 respectively. Location and altitude of the sample plots were determined using altimeter and GPS (Fig. 1).

**Table 1.** The list and abbreviation of 56 species more than 3 occurrences throughout the data set in 56 sample plots of the Buldan district of Southern Anatolia, Turkey

| | | | |
|---|---|---|---|
| **ADECOM** | *Adenocarpus complicatus* (L.) Gay | **PALSPI** | *Palirus spina-cristi* Mill. |
| **AILALT** | *Ailanthus altissima* Mill. | **PINBRU** | *Pinus brutia* Ten. |
| **ALNORI** | *Alnus orientalis* Dence var. *pubescens* | **PINNIG** | *Pinus nigra* Arn. |
| **ASPACU** | *Asparagus acutifolius* L. | **PISTER** | *Pistacia terebinthus* L. |
| **ASTRAG** | *Astragalus* sp. | **PLAORI** | *Platanus orientalis* L. |
| **BORHEL** | *Heliotropium hirsutissimum* Graver | **POATRI** | *Poa trivialis* L. |
| **CANSAT** | *Cannabis sativa* L. | **POPTRE** | *Populus tremula* L. |
| **CARMAR** | *Carduus marianus* L. | **POTREC** | *Potentilla recta* L. |
| **CARCOR** | *Carlina corymbosa* L. | **PRUDIV** | *Prunus divarcata* Ledeb. |
| **CHENOP** | *Chenopodium botrys* L. | **PYRCOM** | *Pyrus communis* L.. |
| **CIRARV** | *Cirsium arvense* (L.) Scop. | **QUECER** | *Quercus cerris* L. |
| **CISLAU** | *Cistus laurifolius* L. | **QUECOC** | *Quercus coccifera* L. |
| **CISCRE** | *Cistus creticus* L. | **QUEILE** | *Quercus ilex* L. |
| **COLORI** | *Colutea orientalis* Mill. | **QUEINF** | *Quercus infectoria olivier* |
| **CONJUN** | *Condrilla juncea* L. | **QUEITH** | *Quercus ithabureensis* Decn |
| **CRAMON** | *Crategus monogina* Jacq. | **ROBPSE** | *Robinia pseudoacacia* L. |
| **CREPİS** | *Crepis* sp. | **ROSCAN** | *Rosa canina* L. |
| **CUPSEM** | *Cupressus sempervirens* L. | **RUBCAN** | *Rubus canensis* DC. |
| **DRYPAL** | *Dryopteris pallida* (Bory) Fomin. | **SALNIG** | *Salix nigra* Marsh. |
| **ECHITA** | *Echium italicum* L. | **SALCAP** | *Salix caprea* L. |
| **ERYCAM** | *Eryngium campestre* L. | **SCACOL** | *Scabiosa columbaria* L. |
| **EUPHEL** | *Euphorbia helioscopia* L. | **SILCOM** | *Silene compacta* Fischer |
| **HEDHEL** | *Hedera helix* L. | **SPAJUN** | *Spartium junceum* L. |
| **HIBSYR** | *Hibiscus syriacus* L. | **STYOFF** | *Styrax officinanis* L. |
| **LATLAX** | *Lathyrus laxiflorus* (Desf.) O. Kuntze | **VERBAS** | *Verbascum* sp. |
| **NEPNUD** | *Nepeta nuda* L. | **VITAGN** | *Vitex agnus-castus* L. |
| **OLEOLE** | *Oleaa oleaster* L. | **XANSTR** | *Xanthium strumarium* L. |
| **ONOSPİ** | *Ononis spinosa* L. | **ZIZCLE** | *Ziziphora taurica* Bieb. Subsp. *cleonioides* (Boiss) |

**Table 2.** The list and abbreviation of 56 species more than 3 occurrences throughout the data set in 56 sample plots of the Buldan district, of southern Anatolia, Turkey

| | | | |
|---|---|---|---|
| **ALTITU** | Altitude (m) | **BSTONE** | Bv horizon stoniness (%) |
| **SLOPE** | Slope degree (%) | **BLIME** | Bv total calcium carbonate (%) |
| **SDEPTH** | Soil depth (cm) | **BORG** | Bv horizon organic matter (%) |
| **SSTONE** | Soil stoniness (%) | **BPH** | Bv horizon soil pH |
| **SPOSTN** | Slope position | **BEC** | Bv horizon electrical conductivity (μ) |
| **ASPECT** | Aspect | **BCLAY** | Bv horizon clay (%) |
| **GNAYY** | Precambrien aged gneiss | **BDUST** | Bv horizon dust (%) |
| **GRANT** | Miosen aged granite | **BSAND** | Bv horizon sand (%) |
| **SHIST** | Paleozoic schistose quarzite | **BFIELD** | Bv horizon field capacity (%) |
| **ALUVYN** | Quaterner alluvion deposits | **BWILPON** | Bv horizon permanent wilting capacity (%) |
| **PLİMAT** | Pliocene aged sandstone claystone deposits | **BWATER** | Bv horizon available water capacity (%) |
| **ADEPTH** | Ah horizon depth (cm) | **CDEPTH** | Cv horizon depth (cm) |
| **ASTONE** | Ah horizon stoniness (%) | **CSTONE** | Cv horizon stoniness (%) |
| **ALIME** | Ah total calcium carbonate (%) | **CLIME** | Cv total calcium carbonate (%) |
| **AORG** | Ah horizon organic matter (%) | **CORG** | Cv horizon organic matter (%) |
| **APH** | Ah horizon soil pH | **CPH** | Cv horizon soil pH |
| **AEC** | Ah horizon electrical conductivity (μ) | **CEC** | Cv horizon electirical conductivity (μ) |
| **ACLAY** | Ah horizon clay (%) | **CCLAY** | Cv horizon clay (%) |
| **ADUST** | Ah horizon dust (%) | **CDUST** | Cv horizon dust (%) |
| **ASAND** | Ah horizon sand (%) | **CSAND** | Cv horizon sand (%) |
| **AFIELD** | Ah horizon field capacity (%) | **CFIELD** | Cv horizon field capacity (%) |
| **AWILPON** | Ah horizon permanent wilting capacity (%) | **CWILPON** | Cv horizon permanant wilting capacity (%) |
| **AWATER** | Ah horizon available water capacity (%) | **CWATER** | Cv horizon available water capacity (%) |
| **BDEPTH** | Bv horizon depth (cm) | | |

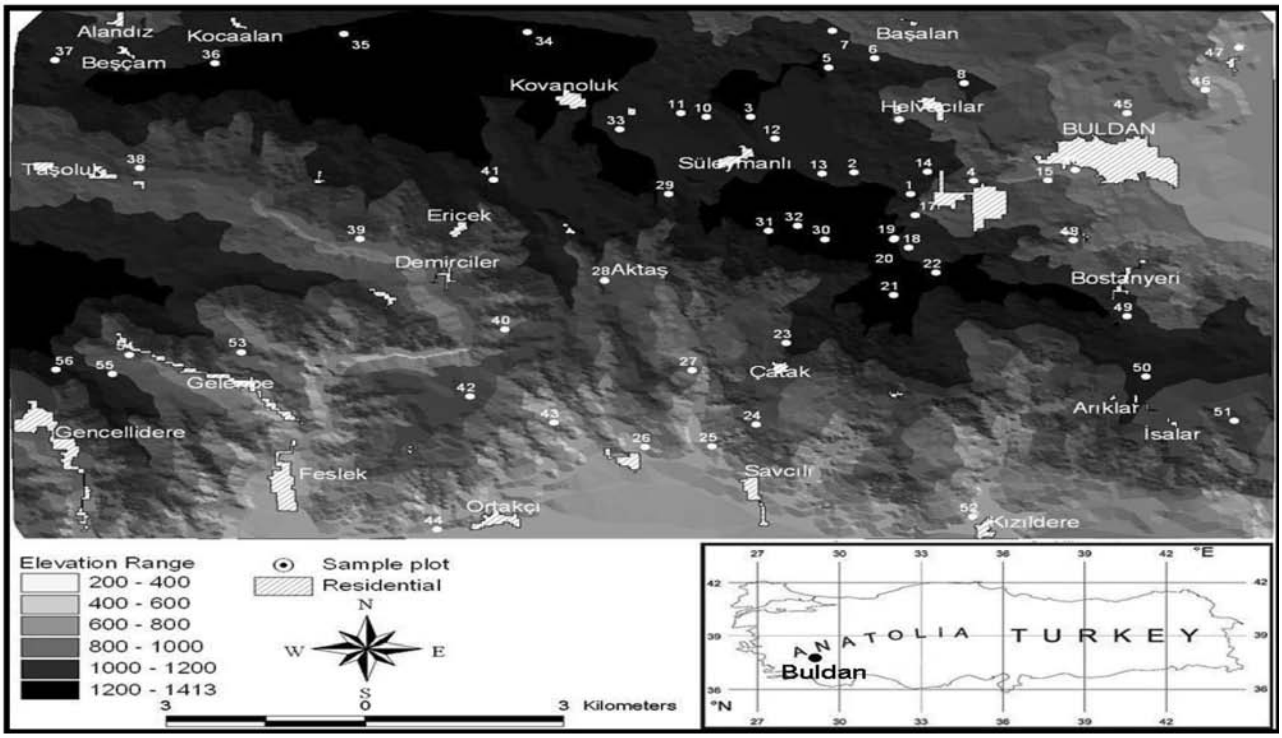


**Fig. 1.** Location of sample plots in Mediterranean mountain forest in the Buldan forest district of southern Anatolia, Turkey

Slope (%) was measured using clinometers. Slope position was determined in the sample plots and controlled on the topographic map. The variable was recorded as 1 (valley bottom), 2 (lower slope), 3 (middle slope), 4 (upper slope) and 5 (ridges), respectively (Dasdemir 1992; Ozkan *et al.* 1998). Aspect was recorded using a compass. Aspect variable was arranged from shallow aspects to sunny aspects as 1(north), 2 (northern east and northern west), 3 (west and east), 4 (southern east and southern west) and 5 (south) and recorded in dataset (Hahs *et al.* 1999; Ozkan 2006b). Each parent material was accepted as a new variable and recorded presence (1) and absence (0) in data set (Ozkan 2004).

Soil survey was done according to Kantarci (2000). The soil samples were collected from Ah (enrichment of humus), Bv (iron oxidation, mineral new formation) and Cv (output rock with only weak decomposition) horizons at each site and were analyzed according to the following methods. The texture by hydrometer method (Bouyoucos 1962), pH with glass electrode (1/2.5 soil-solution ratio) (Jackson 1958), total inorganic carbonate with Scheibler calcimeter (Allison and Moodie 1965), Electrical conductivity (EC) with conductivity probe (Jackson 1958) and organic matter by Wakley-Black wet oxidation method (Walkey and Black 1934). Field capacity and permanent wilting capacity were determined using pressure plate apparatus and available water contents (%) calculated as the difference between them (Klute 1986).

### 2.3. Data analysis

Multivariate methods have been widely preferred for vegetation data to detect the vegetation pattern and explore the species-environment relationships (Ter Braak 1987; Jeglum and He 1995; Martin and Bouchard 1993; Pinto *et al.* 2006; Fontaine *et al.* 2007).

In this paper, canonical correspondence analysis based on linear regression (CCA) was performed with Program Linear-Polynomial RDACCA of Makerenkov and Legendre (2002). The effects of environmental characteristics on vegetation pattern are directly quantified by CCA. In this way sample sites and species are directly ordinated under the constraint of environmental variables (Makerenkov and Legendre 2002).

Correlation coefficients and significant levels between the site scores of the first two axes of the CCA, 47 environmental variables, richness, woody vegetation and total vegetation cover were calculated using Spearman rank correlation analysis (Ozdamar 1999).

## 3. Results and Discussions

### 3.1. Canonical correspondence analysis

The total inertia (sum of all the eigenvalues) of species data in the 56 plots was 4.44575, and the sum of the canonical eigenvalues was 3.68919. The cumulative percent variance of species data for all the axes was 82.98%. The P value was 0.001 after 999 permutations.

The eigenvalues for the first four axes were 0.68324, 0.40696, 0.39740, and 0.28451. The cumulative percent variance of species data for the first two axes was 24.52%. A two-dimensional CCA ordinates of the 56 sample plots is shown in Fig. 2.

The environmental control of vegetation patterns in Fig. 2 can be further interpreted by correlating the ordinate scores of plots for the first two axes with sampled environmental variables. There were significant correlations between axis I and ALTITU, BWATER, ASPECT, BFIELD, SHIST, SSTONE etc. (Table 3). We interpreted axis I as an altitude-aspect gradient. Axis II was significantly correlated with ALIME, BLIME, BPH, SHIST, CPH, APH, SLOPE, AEC, ASAND, CWILPON respectively (Table 3). We interpreted axis II as a pH-calcium carbonate gradient.

POATRI, CISLAU, PINNIG, RUBCAN etc. in the upper left quadrant occupied by SHIST, ASAND and ROSCAN, ERYCAM, PRUDIV, CARMAR, etc. in the lower left quadrant occupied by BWATER, BFIELD are positioned in the higher altitudinal range and shadow aspects. On the contrary, PINBRU, OLEOLE, QUEILE, QUECOC etc. from the lower right quadrant occupied by APH, BPH, ALIME, BLIME and PISTER, PALSPI, SPAJUN, CISCRE, STYOFF, etc. from the upper right quadrant occupied by SLOPE are positioned in the lower altitudinal range and sunny aspects (Fig. 3).

### 3.2. Environment and diversity

The influence of environmental variables on the species richness, woody vegetation and total vegetation cover are shown in Table 4.

Species richness is unrelated to the first axes (altitude-aspect gradient) of the CCA ordinates but it is significantly negatively correlated with the second axis (pH-total calcium carbonate gradient). Among the environmental variables, ALIME, BDEPTH, BLIME, BPH, CPH are positively correlated with species richness, whereas SHIST shows negative correlations ($p<0.05$).

Woody vegetation cover is only negatively correlated with ASPECT at the level of 0.05. On the other hand, Woody vegetation cover tends to decrease from shadow aspects to sunny aspects.

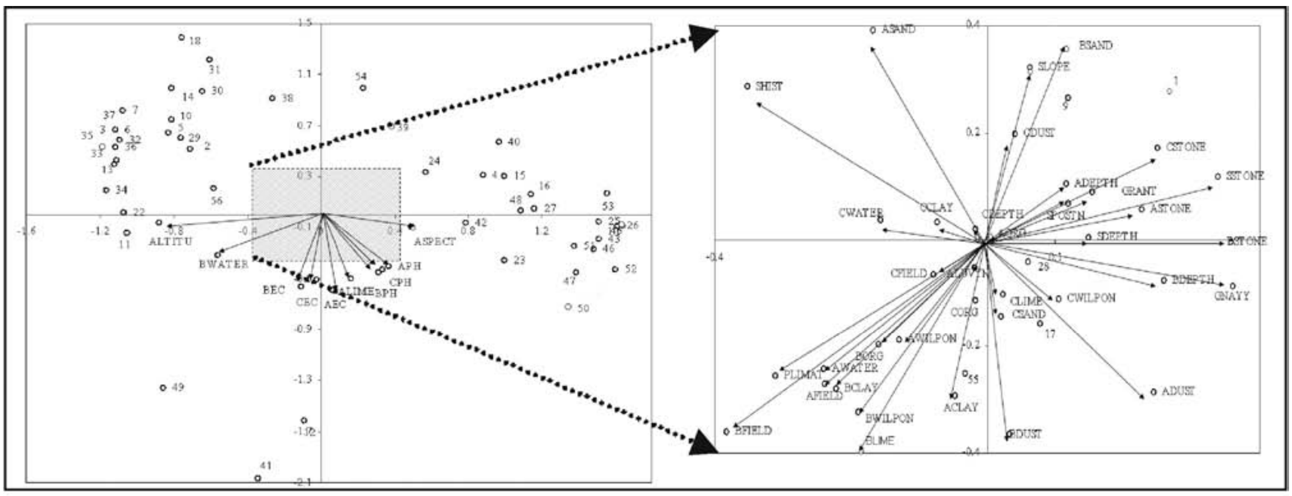


**Fig. 2.** Canonical correspondence analysis of sample plots in the Buldan district of Southern Anatolia

**Table 3.** Spearman rank correlation coefficients among 47 environmental variables and site scores of axes I and II of CCA

| | Axis 1 | | Axis 2 | | | Axis 1 | | Axis 2 | |
|---|---|---|---|---|---|---|---|---|---|
| | Correlation | p | Correlation | p | | Correlation | p | Correlation | p |
| **ALTITU** | –0.847 | 0.000 | 0.217 | 0.109 | **BSTONE** | 0.411 | 0.002 | –0.179 | 0.187 |
| **SLOPE** | 0.060 | 0.658 | 0.391 | 0.003 | **BLIME** | 0.293 | 0.028 | –0.512 | 0.000 |
| **SDEPTH** | 0.138 | 0.311 | –0.076 | 0.576 | **BORG** | –0.221 | 0.101 | –0.046 | 0.739 |
| **SSTONE** | 0.333 | 0.012 | –0.012 | 0.930 | **BPH** | 0.237 | 0.078 | –0.466 | 0.000 |
| **SPOSTN** | 0.143 | 0.295 | 0.007 | 0.957 | **BEC** | –0.073 | 0.592 | –0.219 | 0.105 |
| **ASPECT** | –0.847 | 0.000 | –0.128 | 0.348 | **BCLAY** | –0.283 | 0.035 | –0.051 | 0.708 |
| **GNAYY** | 0.060 | 0.012 | –0.194 | 0.153 | **BDUST** | 0.078 | 0.566 | –0.185 | 0.171 |
| **GRANT** | 0.138 | 0.237 | 0.007 | 0.958 | **BSAND** | 0.049 | 0.720 | 0.219 | 0.105 |
| **SHIST** | 0.333 | 0.005 | 0.439 | 0.001 | **BFIELD** | –0.426 | 0.001 | –0.010 | 0.941 |
| **ALUVYN** | 0.143 | 0.957 | –0.184 | 0.175 | **BWILPON** | –0.307 | 0.022 | –0.113 | 0.405 |
| **PLİMAT** | –0.847 | 0.014 | –0.051 | 0.706 | **BWATER** | –0.564 | 0.000 | 0.158 | 0.244 |
| **ADEPTH** | 0.060 | 0.715 | 0.152 | 0.263 | **CDEPTH** | 0.017 | 0.903 | –0.037 | 0.788 |
| **ASTONE** | 0.138 | 0.033 | 0.024 | 0.860 | **CSTONE** | 0.268 | 0.046 | 0.070 | 0.609 |
| **ALIME** | 0.333 | 0.014 | –0.528 | 0.000 | **CLIME** | 0.073 | 0.595 | –0.201 | 0.138 |
| **AORG** | 0.143 | 0.705 | 0.025 | 0.856 | **CORG** | –0.114 | 0.402 | –0.077 | 0.571 |
| **APH** | –0.847 | 0.019 | –0.404 | 0.002 | **CPH** | 0.265 | 0.049 | –0.415 | 0.001 |
| **AEC** | 0.060 | 0.093 | –0.342 | 0.010 | **CEC** | 0.071 | 0.601 | –0.256 | 0.057 |
| **ACLAY** | 0.138 | 0.983 | –0.158 | 0.246 | **CCLAY** | –0.090 | 0.509 | –0.044 | 0.749 |
| **ADUST** | 0.333 | 0.073 | –0.295 | 0.027 | **CDUST** | 0.109 | 0.424 | 0.021 | 0.878 |
| **ASAND** | –0.203 | 0.134 | 0.312 | 0.019 | **CSAND** | –0.034 | 0.805 | –0.056 | 0.684 |
| **AFIELD** | –0.202 | 0.136 | –0.040 | 0.769 | **CFIELD** | –0.098 | 0.471 | –0.113 | 0.407 |
| **AWILPON** | –0.106 | 0.438 | –0.113 | 0.406 | **CWILPON** | 0.011 | 0.934 | –0.271 | 0.043 |
| **AWATER** | –0.329 | 0.013 | 0.105 | 0.443 | **CWATER** | –0.289 | 0.031 | 0.108 | 0.427 |
| **BDEPTH** | 0.197 | 0.145 | –0.155 | 0.255 | | | | | |

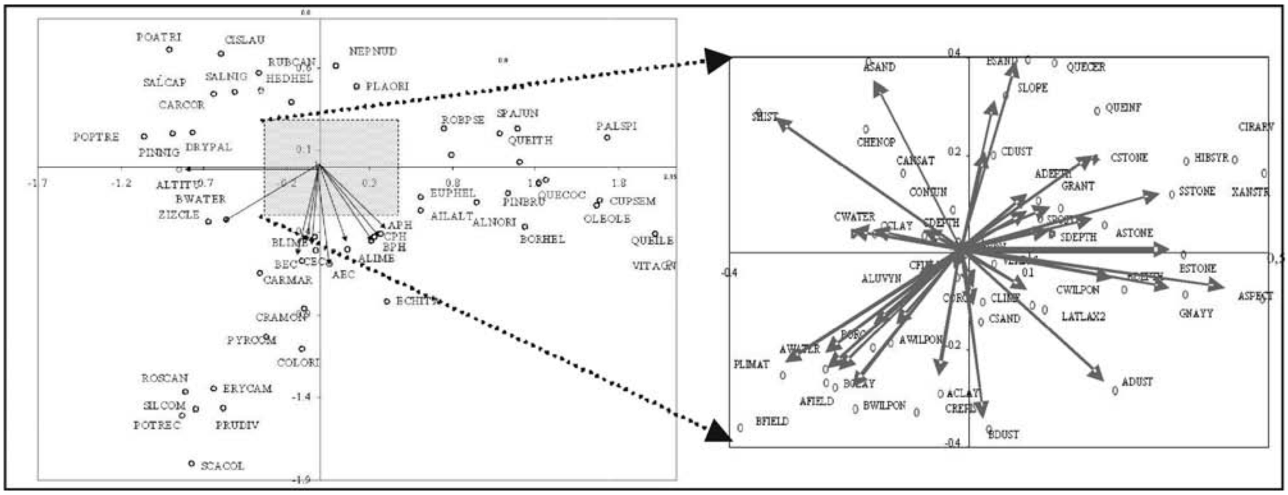


**Fig. 3.** Canonical correspondence analysis of plant species in the Buldan district of southern Anatolia

Total vegetation cover is significantly correlated with the first axes (altitude-aspect gradient) of CCA ordinates but insignificantly correlated with the second axes (pH-total calcium carbonate gradient) of CCA. Total vegetation cover is negatively correlated with ASPECT like Woody vegetation. At the same time, it is positively related to AFIELD, AWATER, BDUST, BFIELD, BWATER and CWATER ($p<0.05$). The relation of total vegetation cover with axes I originated from ASPECT. In other words, ASPECT and water capacity of soils are the most important factors affecting total vegetation cover.

## 4. Conclusions

Axis I represented altitude-aspect gradient. On the other hand, the distribution of vegetation clearly defines an altitudinal and exposition series. Similar results were reported by Kantarci (1998), Atalay (1987), Ozkan (2003), Karatepe (2003) and Fontaine *et al.* (2007) in different districts of Mediterranean region.

The vegetation in the lower elevation (below 800 m) and the sunny aspects (the southern range of the mountainous mass) represents a Eu-Mediterranean community dominated by *Pinus brutia* with associated species such as *Olea oleaster, Quercus ilex, Quercus coccifera, Pistacia terebinthus, Paliurus spina-christi,*

**Table 4.** Spearman rank correlations among species richness, woody vegetation cover, total vegetation cover and site scores of the first two axes, 47 environmental variables in the Buldan district vegetation communities

| | Richness number species | | Woody vegetation cover | | Total vegetation cover | |
|---|---|---|---|---|---|---|
| | Correlation | p | Correlation | p | Correlation | p |
| **ax1** | 0.141 | 0.299 | –0.064 | 0.639 | –0.327 | 0.014 |
| **ax2** | –0.405 | 0.002 | 0.037 | 0.784 | 0.205 | 0.130 |
| **ALTITU** | –0.085 | 0.531 | –0.126 | 0.354 | 0.173 | 0.203 |
| **SLOPE** | 0.118 | 0.386 | 0.062 | 0.652 | 0.023 | 0.869 |
| **SDEPTH** | 0.209 | 0.121 | 0.075 | 0.584 | –0.089 | 0.512 |
| **SSTONE** | 0.193 | 0.153 | 0.131 | 0.337 | 0.112 | 0.412 |
| **SPOSTN** | 0.218 | 0.106 | 0.138 | 0.310 | 0.127 | 0.350 |
| **ASPECT** | 0.063 | 0.644 | –0.283 | 0.034 | –0.388 | 0.003 |
| **GNAYY** | 0.142 | 0.296 | –0.133 | 0.330 | –0.174 | 0.199 |
| **GRANT** | –0.016 | 0.906 | 0.063 | 0.647 | –0.080 | 0.556 |
| **SHIST** | –0.275 | 0.040 | 0.134 | 0.326 | 0.189 | 0.163 |
| **ALUVYN** | 0.025 | 0.857 | 0.049 | 0.719 | 0.034 | 0.801 |
| **PLİMAT** | 0.086 | 0.528 | –0.043 | 0.754 | 0.148 | 0.276 |
| **ADEPTH** | 0.129 | 0.344 | 0.172 | 0.206 | 0.110 | 0.419 |
| **ASTONE** | –0.055 | 0.686 | –0.047 | 0.730 | –0.059 | 0.665 |
| **ALIME** | 0.448 | 0.001 | 0.153 | 0.260 | 0.170 | 0.209 |
| **AORG** | –0.025 | 0.855 | –0.135 | 0.320 | –0.137 | 0.314 |
| **APH** | 0.257 | 0.056 | –0.097 | 0.478 | –0.118 | 0.387 |
| **AEC** | 0.092 | 0.498 | –0.143 | 0.293 | –0.171 | 0.208 |
| **ACLAY** | 0.114 | 0.404 | –0.164 | 0.227 | –0.057 | 0.675 |
| **ADUST** | 0.186 | 0.169 | 0.062 | 0.649 | 0.073 | 0.592 |
| **ASAND** | –0.209 | 0.122 | –0.010 | 0.939 | –0.076 | 0.576 |
| **AFIELD** | 0.090 | 0.509 | 0.102 | 0.455 | 0.296 | 0.027 |
| **AWILPON** | 0.107 | 0.431 | –0.019 | 0.890 | 0.125 | 0.360 |
| **AWATER** | 0.029 | 0.834 | 0.157 | 0.247 | 0.412 | 0.002 |
| **BDEPTH** | 0.424 | 0.001 | 0.176 | 0.195 | 0.088 | 0.517 |
| **BSTONE** | 0.179 | 0.187 | 0.104 | 0.446 | 0.050 | 0.714 |
| **BLIME** | 0.382 | 0.004 | 0.043 | 0.751 | 0.079 | 0.564 |
| **BORG** | 0.107 | 0.435 | –0.017 | 0.899 | 0.083 | 0.543 |
| **BPH** | 0.323 | 0.015 | –0.051 | 0.711 | –0.114 | 0.404 |
| **BEC** | 0.050 | 0.712 | –0.071 | 0.605 | 0.003 | 0.983 |
| **BCLAY** | 0.136 | 0.316 | –0.119 | 0.382 | 0.074 | 0.589 |
| **BDUST** | 0.224 | 0.098 | 0.148 | 0.277 | 0.244 | 0.070 |
| **BSAND** | –0.262 | 0.051 | –0.045 | 0.741 | -0.201 | 0.138 |
| **BFIELD** | 0.040 | 0.769 | 0.108 | 0.428 | 0.328 | 0.014 |
| **BWILPON** | 0.055 | 0.686 | 0.010 | 0.944 | 0.179 | 0.186 |
| **BWATER** | 0.065 | 0.633 | 0.152 | 0.265 | 0.443 | 0.001 |
| **CDEPTH** | 0.080 | 0.558 | –0.059 | 0.668 | –0.174 | 0.200 |
| **CSTONE** | 0.105 | 0.442 | 0.114 | 0.405 | 0.087 | 0.525 |
| **CLIME** | 0.266 | 0.048 | –0.086 | 0.527 | 0.073 | 0.592 |
| **CORG** | –0.146 | 0.285 | –0.136 | 0.317 | –0.176 | 0.195 |
| **CPH** | 0.423 | 0.001 | 0.078 | 0.568 | 0.021 | 0.877 |
| **CEC** | 0.156 | 0.251 | –0.002 | 0.990 | –0.013 | 0.927 |
| **CCLAY** | –0.048 | 0.728 | –0.229 | 0.090 | –0.138 | 0.312 |
| **CDUST** | –0.018 | 0.896 | 0.067 | 0.621 | 0.179 | 0.187 |
| **CSAND** | 0.006 | 0.965 | 0.026 | 0.849 | –0.114 | 0.404 |
| **CFIELD** | 0.032 | 0.814 | 0.043 | 0.752 | 0.151 | 0.267 |
| **CWILPON** | 0.052 | 0.705 | –0.168 | 0.215 | –0.062 | 0.651 |
| **CWATER** | 0.012 | 0.930 | 0.222 | 0.099 | 0.349 | 0.008 |

*Spartium junceum, Cistus cretaegus, Strax officinalis* in Buldan district. These species are typical for the Eu-Mediterrenina maquis (Atalay 1987; Karatepe 2003; Boydak 2004; Fontaine *et al.* 2007). Eu-Mediterranean zone can receive the warm impacts coming from the south. Hence, drought period of Eu-Mediterranean zone prevails more than the remanding areas in the Buldan district.

A translation climate between Eu-Mediterranean and the mountainous Mediterranean climate prevails above 800 m and shadow aspects (the northern range of mountainous mass) – in the district. *Pinus nigra* is dominant tree species. Besides, *Poa trivialis, Cistus laurifolius, Rubus canensis, Rosa canina, Prunus divarcata* and *Carduus marianus* are common species in this translation zone defined Subra-Mediterranean zone.

The mountainous Mediterranean climate arises above 1400 m in Aglasun district (Fontaine *et al.* 2007), above 1450 m – in Egirdir watershed (Kantarci 1998), above 1200 m – in Beyşehir watershed. Lower altitudinal level of the mountainous Mediterranean zone is less in Beysehir watershed compared to Egirdir watershed and Aglasun district. The district is closed to the warm impacts partly coming from Mediterranean Sea, however, Egirdir watershed and Aglasun district have received the warm impacts coming from Mediterranean Sea via Kovada channel (Kantarci 1998; Fontaine *et al.* 2007). There is no typical Mountainous Mediterranean zone in Buldan district. The district can take the impacts coming from the Mediterranean Sea and the highest ridge is only 1413 m.

Axis II represented pH-total calcium carbonate gradient. It was surprising to find this result because, it wasn't found any relationships between distribution of vegetation and pH, total calcium carbonate in the investigations reported by Ozkan (2003), Karatepe (2003) and Fontaine *et al.* (2007) in Mediterranean region. The reason of this is probably concerning with the differences in the amount of parent materials of study areas. Limestone is predominant material in Beysehir watershed, Egirdir watershed, Aglasun district, whereas limestone is absent and gneiss, lime less bedrock, is predominant in Buldan district. On the other hand, pH-total calcium carbonate gradient seems to depend on bedrock properties. Kantarci (1998) stated that the most important factor influencing distribution of vegetation is bedrock in the same altitudinal and expositional ranges in Mediterranean region. Some species such as *Pinus brutia, Olea oleaster, Quercus ilex* and *Quercus coccifera* seems as the characteristic species on the neutral or slightly alkaline soils in CCA ordinates. In general, these species appear on similar pH values in the other districts (Karatepe 2003; Ozkan 2003; Boydak 2004; Fontaine *et al.* 2007).

Species richness has negative correlation with schistose quartzite and positive correlations with the variables, total calcium carbonate in Ah and Bv and pH in Bv and Cv, in the meaning of pH – total calcium carbonate gradient (axes II). The soils derived from limeless schistose quartzite are very shallow and stony. The soil is also very poor in terms of organic matter (Ozkan *et al.* 2006). Hence, many species can't resist these conditions. Therefore, species richness in limeless schistose quartzite is poorer compared to species richness in the other parent materials in the Buldan district.

With the increasing of pH depended on increasing of total calcium carbonate, species richness tends to increase. Limestone is characteristic in Mediterranean region in spite of its absence from Buldan district. Because of this, the soils are neutral or slightly alkaline in general (Atalay 1987; Kantarci 1998) and many species are adapted to these conditions in Mediterranean region. Hence, the plant species richness tends to increase throughout the neutral and slightly alkaline conditions in the Buldan district.

Woody vegetation and total vegetation cover are strongly related to aspect. The coverage values tend to increase from sunny aspects to shadow aspects. This is a moisture gradient. Drought period is approximately 5 months in a year (Ozkan *et al.* 2006). Therefore, the water situation in the soil, particularly during the summer period, is the most important factor effecting vegetation coverage. Besides, total vegetation cover is higher in higher altitudinal range. At the same time, the places being high percentage of field capacity and available water capacity in Ah and Bv horizons have high total vegetation cover. In this situation, soil is probably more important for herbaceous species compared to woody species.

Buldan district have been the theatre of intense human activity for hundred years. Degraded and unproductive forest areas and forestless areas are dominated in the district. Therefore, represented vegetation-environment relationships are very important for preparation of an integrated management plan in terms including restoration, afforestration, conservation, utilization and sustainability in Buldan district.

## Acknowledgements

We acknowledge Scientific Research Projects Committee in Suleyman Demirel University which provided financial support to this study.

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## AUGALIJOS IR APLINKOS VEIKSNIŲ SĄSAJOS VIDURŽEMIO JŪROS BASEINO KALNŲ MIŠKUOSE

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Santrauka

Pagrindinės Pietų Anatolijos (Turkija) miškų išteklių nykimo priežastys – per dideli medienos kirtimo mastai, augimviečių nuganymas ir gaisrai. Atkuriant, želdant miškus, naudojant išteklius ir siekiant užtikrinti šių dalykų darną, turi būti ištirta augalijos ir aplinkos veiksnių tarpusavio sąsaja. Tyrimams duomenys imti iš Viduržemio jūros baseino kalnų miškų, augančių mažo kalkingumo uolienose Pietų Anatolijoje. Augimviečių dirvožemio tipai labai įvairūs. Pasirinkta 56 pavyzdiniai ploteliai, taikyta kanoninio panašumo analizė. Rezultatai rodo, kad du augalijos vegetacijos gradientai susiję su kompleksu veiksnių – teritorijos aukščiu ir dirvožemio pH, nustatomu naudojant $CaCO_3$. Atlikus tyrimus, pirmojoje aplinkos veiksnių grupėje koreliavo teritorijos aukštis, augalų pasisavinama vandens dalis Bv dirvožemio horizonte, šio dirvožemio horizonto derlingumas. Antrojoje aplinkos veiksnių grupėje – Ah procentinė kalkių dalis, kvarcito sluoksnis, Cv, Ah ir Bv horizontų pH, šlaito nuolydžio laipsnis. Rūšies gausa priklausė nuo pH, o bendra augalijos danga buvo susijusi su aukščio gradientu.

**Reikšminiai žodžiai:** Viduržemio jūros baseino miškai, kanoninio panašumo analizė, vegetacijos modelis, aplinkos veiksniai, įvairovė, *Pinus brutia*, *Pinus nigra*.

## РАСТИТЕЛЬНОСТЬ ГОРНЫХ ЛЕСОВ НА НЕИЗВЕСТКОВОЙ ПОРОДЕ ОКРЕСТНОСТЕЙ СРЕДИЗЕМНОМОРЬЯ В ЮЖНОЙ АНАТОЛИИ (ТУРЦИЯ)

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Резюме

Леса Южной Анатолии исчезают из-за получения древесины, большого потравления и пожаров. При решении проблем восстановления, озеленения, охраны, использования и содержания лесов следует знать, каково воздействие факторов окружающей среды на растительность. Исследовались горные леса бассейна Средиземного моря, растущие на горных неизвестковых породах. Результаты показали значение для растительности двух градиентов: высоты и pH ($CaCO_3$). Ось ординат I в значительной мере зависит от высоты, доступности воды Bv (%), каменистости почвы (%) и др. На оси II установлена большая зависимость от общего количества извести в слоях Ah и Bv, pH в слоях Cv и Ah и угла откоса. Многообразие сортов растительности коррелировалось с градиентом pH ($C_aCO_3$), в то время как общее покрытие растительности коррелировалось с градиентом высоты.

**Ключевые слова:** леса бассейна Средиземного моря, анализ канонического подобия, модель вегетации, факторы окружающей среды, разнообразие, *Pinus brutia*, *Pinus nigra*..

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