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Full Length Research Paper

Canonical and typological analysis of the relationship between soil and trees - A step toward ecosystem management

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The goal of this study was to establish a correlation between physico-chemical soil properties and tree species composition using Canonical Correspondence Analysis (CCA). After eliminating the statistically insignificant soil chemical and physical parameters from the correlation analysis, five factors remained: soil drainage, drought throughout the soil, drought in the root layer and dryness in the topsoil during the vegetation period, the average depth of the soil and the average depth of the root layer. The forest-typological basis was analyzed using data modified from studies such as phytocoeonological studies (state guidelines and intensity of succession processes), studies of the hydro-physical properties of the soil and studies of vegetation data for classes of development. The most significant correlations, without exception, proved to be "saturated (stagnant) soil water" and "day of drought in the upper soil zone" (axes F1 and F2) which together explained 75 to 85% of the variance. The results show that hornbeam demonstrates the highest flexibility and durability in stagnant groundwater and avoids dry soils. Oak was more drought resistant, and its occurrence is therefore dependent on the depth of the root system. Beech does not tolerate dry soils. The results of the forest-typological analysis were used to map the distribution of tree species and the soil moisture deficit and they show clear similarities.

Key words: Canonical correspondence analysis, humidity of the soil, forest typology, ecosystem management.

INTRODUCTION

Modern forestry business consists of three main interrelated areas: ecosystem management, multi-purpose planning and integration with other economic sectors. According to Taylor et al. (2009), "successful implementation of ecosystem management requires strategic forest management planning including the ability to forecast future forest composition". In this context, successful forecasting requires forest ecological modeling, particularly the modeling of “qualitative” or “quantitative” succession processes depending on the study’s objectives. The “qualitative” and “quantitative” models were defined by Taylor et al. (2009) as follows: qualitative models are used to gain theoretical understanding of forest processes, whereas quantitative models can be categorized as being "empirical - based on observations of the inheritance process, mechanistic - based on environmental data and knowledge and hybrid - based on combination of mechanical and empirical approaches". There are many models used to study ecosystem dynamics including GAP-modeling, general linear model (GLM), GAM, FORET and Generic seaRch algorithm for the satisfiability problem (GRASP) (Tabari et al., 2005; Rozenbergar et al., 2006; Kenderes et al., 2007; Bord and O’Connor, 1997; Lehmann et al., 2002; Zhu and Kang, 2007). There have been numerous studies of forest succession (West et al., 1981; Shugard, 1984; Abrams and Scott, 1989; Liu and Ashton, 1995; Gustafson et al., 2000), and these studies benefit from the inclusion of a variety of factors (fires, ice storms,

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wind-throw, insect attack and herbicide spraying, wind, geographical spread of seeds and timber harvesting). However, any model must be able to be linked to the natural site of origin (forest) and its agents (stands). This requires an analysis of the correlations between individual factors and individual tree species.

Recently, regression and ordination techniques have been combined in a multivariate direct gradient analysis called canonical ordination (Jongman et al., 1987; ter Braak and Prentice, 1988). Canonical correspondence analysis (CCA) provides the classification and distribution of them under the principles' ordination and the species' density (ter Braak, 1989). In short, CCA is a multivariate statistical analysis technique, displaying the degree of the relationships between the clusters formed using both dependent and independent variables (Tekin, 1993). CCA is not a multiple regression analysis. Multiple regression analysis deals with the relationship among multiple variables; however, canonical analysis is used to explore the relationship between "p" number of dependent variables and "q" number of independent variables. CCA obtains the canonical functions based on the correlation between two independent canonical varieties, maximizing the correlation between the linear competent which is the set of dependent and independent variables (Ünlükaptan and Yilmaz, 2009). Wang et al. (2006), in the stands studied, the CCA technique determined that the dominant species distribution is much more likely to be controlled by climatic factors than competition among the other species. The effect of the climate on the distribution of tree species is strongest as the dominant tree species within the stands start to decline. Fosaa et al. (2004), also implementing CCA, determined the potential effects of climate change on the distribution of plant species. Tejedor et al. (2004) used CCA to determine how monthly fluctuations in soil humidity influence the distribution of pine species. Furthermore, St-Denis et al. (2010) tested the canonical relationship between the rejuvenation of black pine forests and other factors such as the gaps inside the forests, the amount of light penetrating through the canopy, the age and density of the stand and plant species frequencies.

Canonical and phytocoenological analyses were performed in this study to accomplish several aims: to further define and confirm the results of existing soil and forest-typological studies, to generalize across the study area range, to provide guidance on practical ecosystem management activities and to highlight the importance of these activities at a regional scale. Moreover, the study demonstrates that this type of analysis can provide a basis for conducting a relatively low-intensity, classical terrestrial inventory. This approach may prove valuable for the exploration and mapping of forest habitats. This study attempted to establish a correlation between physico-chemical soil properties and the composition of tree species using CCA. To establish correlations, the following parameters were used: soil drainage, drought throughout the soil, drought in the root layer and drought in the topsoil during the vegetation period, the average depth of the soil and the average depth of the root layer (Table 5).

METHODOLOGY

Study location and material

The study area is situated in the "Bentler" region of the Belgrade Forest, north of Istanbul. The total study area represents 2622 ha, and the area is administrated by the forest service in the form of "protective forests". The area's topography is rather hilly, with smooth, slightly tilted and rounded slopes with broad plateau formations on the ridges. The average elevation of the site is 140 to 150 m. Neocene bedrock represents 84% of the soil, with the remainder derived from silt stones (Kantarci, 1980). The average annual temperature is 12.7°C, with the extreme temperatures at -15.8°C in the winter and 39.7°C in the summer. Annual rainfall in the region is 1080.3 mm, and the average relative humidity is 79.7%. Winters are wet and mild, and summers are semi-arid. Pure stands are in stock, including oak, eastern beech, hornbeam and some very small areas of chestnut. A variety of mixed stand compositions persist: oak and hornbeam; oak and eastern beech; hornbeam and eastern beech; hornbeam, oak and eastern beech; oak and chestnut; and oak, hornbeam and chestnut (Destan, 2001). According to Akkemik et al. (2006), the growing season in the studied area spans the 220 days from 30th of April to the 5th or 6th of December. This study utilized the results of inventories collected in 1990 and 2002 and included 472 areas that were systematically sampled in a pattern to keep the sample areas 300 m apart. Sample areas measured in 2002 were located approximately 100 m south of the sample areas that were systematically sampled in 1990. Other important factors used in the analysis include soil and ecology (Kantarci, 1980; Tunçkale, 1965).

Kantarci (1980) explored the following, relatively important parameters of soil: 1) soil depth: absolute depth – the average degree of soil depth (very shallow - ≤ 15; shallow – 15 to 30; average depth – 31 to 60; deep – 61 to 120; very deep ≥ 121 cm); physiological depth – measuring the potential for the spread of the roots; factual depth – the average root depth with roots over Ø2 mm/dm^3 of the soil; 2) soil drainage and stagnant groundwater – saturated (stagnant) soil water is identified by red, yellow and gray spots in the soil profile according to the following grades: ≤ 30 cm - very weak; ≤ 60 cm - weak; ≤ 90 cm – medium; lack of colored patches - good drainage - ≥ 150 cm; 3) humidity of the soil horizons –levels of seasonal humidity, and in particular, the processing of the vegetation period. Water deficit is calculated in millimeters (mm) and the number of drought days. Kantarci also introduced the concept of "hydrological drought" based on the studies of Irmak and Çepel (1968). They found that the vitality of trees was not affected by all soil droughts. Hydrological drought is defined as a 100 mm soil moisture deficit lasting at least 23 days. Yellowing of the tree leaves that later fall off is the most distinctive feature of this type of drought. "Hydrological drought" is calculated by an index of aridity:

$(I_{arid.} = 12_{(months)} * ET_{(real)})$ / maximum average monthly temperature.

Kantarci (1980) analyzed these indicators and established a "soil ecological series" that is linked to local climatic indicators. As a result of his research, Kantarci (1980) identified 64 specific units of local habitats according to their position and micro relief. Data on drainage, a lack of soil moisture and the number of days of soil drought are taken from studies by Kantarci (1980: 214 to 217). The second group of information is the result of typological studies (Destan, 2001).

The forests evaluated by the present study are divided into oak formations with two types of forest formations of eastern beech and chestnut. They were defined according to the updated phyto-coeonotical (Corresponding name for "plant sociology") methods of Pavlov (1998). The description of forest types and forest formations involves the use of edaphic elements such as soil hydrothermal regime and wealth, the type and condition of the living forest (species diversity), and typological formulas of 'mono' and 'polyedificatory' and 'primary' and 'secondary' forest communities. The typological formulas contain information about the current and desired productivity and the desired tree composition and structure, types, tips, guidelines and levels of development of the succession process, and the vertical and horizontal structural stability of the plantation. For each type of forest habitat and tree species, comparative analyses were made and succession models of current forest ecosystems were established. The results were expressed in typological formulas for each type of forest. Using these models and formulas for the typological composition of preferred tree species in each sample area can define the directionality of the succession (progressive or regressive) and extend to the ongoing succession process.

The results of the study are only valid for the tree groups included in the sample areas, and they are rated on a decimal scale.

Procedure

Determination of a model includes an overview of the information used to classify the data groups and their selection for inclusion in the analysis. The analysis is performed on the basis of the number of different tree species in each sample area and the relevant soil properties. Wood volume was divided by the tree species and the grades of thickness to classify each sample area within the forestry planning and silvicultural systematic. Data from the inventories conducted in 1990 and 2002 were used in the analysis. Although, measurements were taken 10 years apart, the tree proportions remained the same. Sample areas are classified based on the "Instructions of Forest Management (1993)" in Turkey. These instructions state that they are divided into the following categories by diameter: 1.0 to 7.9 cm is labeled with the symbol "a"; young (8.0 to 19.9 cm) is labeled with the symbol "b"; ripening (20.0 to 35.9 cm) is labeled with the symbol "c"; ripe (36.0 to 51.9 cm) is labeled with the symbol "d"; and senescent (≤ 52.0 cm) is labeled with the symbol "e". A combination of these categories is used to denote stem volume characters (for example, "bc" or "cd"). The composition is considered to be pure as long as the contribution of other tree species does not exceed 10% of the total stem volume. The proportion of each tree species in the mixture is symbolized as one tenth of the overall volume. For the final summaries, each sample area is analyzed according to the vertical structuring (subordinate and dominant tree species) of the stands.

In CCA, the number of tree species is preferred (Ni/ha), and in silvicultural and typological analysis, the volume of tree species, classes of stem diameter and the vertical structure of stands are considered. The reason for these preferences is in the specific objectives of the two different analyses. CCA seeks to establish a link between the characteristics of the habitat and the species, and it is based on the principle of "presence or not". In contrast, silvicultural and typological analysis is a summary and is based on silvicultural and typological principles. The second group contains hydrothermal and morphological data for soil types in the studied area. In the absence of pronounced relief and climatic variation, pitch-related parameters were excluded from the analysis. Compared with continental Europe, in this region, the sun has a vertical position. Flat areas and very gently sloping hills cover 50% of the territory, and approximately 4% of these hills are steep. The involvement of soil types and soil species, and some related morphological parameters (for example, skeletons) is also ignored in the analysis. The reason for ignoring these parameters is due to the specific consequences these factors have during data analysis: their use in CCA breeds autocorrelation. In connection with these arguments, preferred factors for analysis in this group are provided: absolute depth – the average depth of soil (cm); factual depth – the average root depth (cm); stagnant high groundwater - reciprocal values of the depth of stagnant water from the soil surface 30, 60, 90 and 150 cm); humidity of the soil horizons (physiological drought) – the number of drought days in the upper soil zone, drought days in all soil zones and drought in the root. Information on the "drought start day" during the vegetation period was used in the final analysis. The third group contains typological (phyto-coeonotic) data across a very wide range. The current status of the stands of a given sample size depends on whether it is "primary" or "secondary". A primary (or secondary) is defined by the guidelines governing the intensity and duration of the succession process. Therefore, a special analysis using an existing scale describing the typological status of crops and their classification is based upon phytocoeonotic criteria.

Each stand is rated according to its belonging to a "forest formation" and its corresponding "natural" forest type. In this context, all of the factors and indicators are used to include the potential for strong productivity in each typologically determined planted individual, the preferred stock and the ecosystem (structural) stability. When typologically compared with the optimal ecosystem, the results were rated on the basis of a 10 point grading scale according to the structuring and stability of each planted individual's formation. The optimum condition is reported for the identified optimum forest type to which they belong (that is, the desired composition, the desired structure of tree communities, the processes under the canopy and litter, the optimum productivity and more). An example is presented to provide a generalized overview of this process (Table 1): Notes: B - Eastern beech; O - oak; H - hornbeam; L - lime; vertical construction - "I" species, the dominant layer share and "*I*" species are under-story; Bm(p) - mono and above typological forest soil and hydrological parameters. Subsequently poliedificator mezofit formation of Eastern beech; Og (s) - Gross Oak Forest types within *Quercus Petrea*- *Quercus Frainetto mono* and poliedificator mezofit formation of oak; intensity of the succession process - no process (0), weak (2), intermediate (4), medium fast (6), fast (8) and rapid (10). Example: the experimental area (№ 549) falls within the 'forest formation' "Stranjensis *Qseromezophyth querquethum*", represented by the dominant species *Q. petrea* and *Q. frainetto,* poly-edificatory forest populations; plants in the forest floor include qseromezophyth herbs sinusiums (Destan, 2001). Medium site index – III to IV, the parts II; type - primer, semi stability; Typological formulation of the "big *Q. querquethum*" forest type (mixed and primer); (6 to 7QpIII to II + 6 to 7QfIII to II + *2* to 3CbIII + 1CsIII + FoIII + TIII) / (III to IV11 to 12, C4 to 5, P4), the desired mixture of tree species in the upper layer; 6 to 7Qp III to II + 6 to 7Qf III to II + 1Cs III + 1T + 1Fo III, the desired mixture of tree species in the lower layer; 5 to 6Cb III + 2T III to II + 2Qp III to II + Qf III.

The № 359 experimental area belongs to the soil- environment series, XIX/32. Clay loam soils in the test area are deep (≥120 cm), have very poor drainage (30 cm) and are wet during the winter, and the topsoil is dry in the summer. Due to the presence of stagnant water, root systems are relatively shallow (up to 50 cm). The forest floor and litter cover are semi-typical. Hornbeam has begun to share the status of dominant oak, and at the same time, dominates the under-story, suppressing oak undergrowth. Eastern beech also occurs on the first floor, but its roots cannot tolerate stagnant water. Thus, there is a regression (rated "-4") of moderate intensity (score "6"); forms stands but is a secondary grade "7/3". Such areas are found in experimental areas № 555 and 558, but the undesirable

Table 1. The most important forestry, soil and pfitoceonotic parameters in the inventoried test areas.

Test area no.	Stands in the test area	Stagnant high ground-water (cm)	Drought in upper soil zone (days)	Starting day vej. per.	Drought in all soil zone (days)	Ave-rage soil depth (cm)	depth of root zone (cm)	Drought of root zone (days)	Mixture	
									Tree spec. (m^3/ha) (1/10)	Vertical construction in test area
1	2	3	4	5	6	9	10	11	12	13
359	BO d3	≥150	15	210	0	135	120	0	7;3-(L)	B I O
549	OHB cd3	30	30	200	14	135	50	25	6;3;1	OH (B)/H

Test area no.	Forest type	Succession process		Condition of the stand		Tree species			
		Direction (progressive or regressive)	Intensity process	Primary	Secondary	Dominant (N/ha)	1. Accompanying (N/ha)	2. Accompanying (N/ha)	3. Accompanying (N/ha)
				Participation in (1/10)					
→	14	15	16	17	18	19	20	21	22
359	Bm (p)	1	2	10	0	283 (B)	167(O)	(L)	0
549	Og (s)	-4	6	7	3	460 (O)	160 (H)	60 (B)	0

Notes: B - Eastern Beech; O – oak; H – hornbeam; L – lime; vertical construction – “I” species, the dominant layer share and “/” species are under-storey; Bm (p) - mono and poliedificator mezofit formation of Eastern Beech; Og (s) – gross oak forest types within *Q. Petrea-Q. Frainetto mono* and poliedificator mezofit formation of oak; intensity of the succession process – no process (0), weak (2), intermediate (4), medium fast (6), fast (8), rapid (10).

changes in tree species are more intense. These are ‘geitogenetical’ processes with anthropogenic origin. The estimates relate only to the vegetation cover and the soil conditions in the experimental areas. The adjacent areas (in this study there were 29) are used to analyze the actual performance of an experimental area by evaluating differences in the vegetation. Otherwise, it would violate (ignore) the principle of "presence or not" and the rules of "independent samples". To establish the relationship between the species distribution and the hydro-physical properties of the soil, CANOCO 4.5 software was used (ter Braak and Šmilauer, 2002) to study the distribution of the 4 most important tree species in the region studied: oak (basic types *Q. petrea* Liebl. and *Q. fraineto* Ten.), Eastern beech (*Fagus orientalis* Lipsky), hornbeam (*Carpinus betulus* L.) and chestnut (*Castanea sativa* Mill.).

On the basis of the comparison of soil parameters, the following factors were used in the multifactor analysis: the average depth of soil, the average root depth, saturated (stagnant) soil water, the number of days of drought in the upper soil zone, the number of days of drought in all soil zones, root zone drought and the presence of tree species. First, the data were evaluated to obtain a clear picture of the specific requirements of tree species in the soil conditions found in the studied area. Next, for the purposes of CCA, in the first stage, data were selected and analyzed separately, including 93 clean oak sample areas, 30 sample areas with over 90% beech, 27 sample areas with 80% hornbeam and 16 sample areas with over 70% chestnut. To establish the specific condition of crops in different soil conditions and succession processes472 sample areas were grouped according to the tree species present and their mean diameter (stages of development) in the second stage. For each group that was processed, statistical averages were calculated for the, combined histograms were drawn to enable a visual comparison of the different content parameters. Forest-typological parameters involved in the data matrix were transformed in the following way: a) line of succession - obviously negative (-4), negative (-2), positive (+1), none (0); intensity of succession - maximum (10), very strong (8), strong (6), medium (4), weak (2) none (0); stages of the succession state in sample plots - end (10), ending (8), medium (6), poor (2) and none (0).

The CCA results were compared with a meso-combinational map of the distribution of tree species and the grades of thickness and maps depicting soil drought in the surface and root layers. These maps were produced using the geo-statistical program QGIS based on soil data from the location containing the 472 experimental areas.

RESULTS

The results are presented in stages. The results portraying the validity of the correlation analysis are presented in Tables 2, 3 and 4. At the level of significance of Alpha = 0.050, the null hypothesis there is that no significant correlation between variables is rejected. In other words, the correlation between the variables is significant. Examining the proportion of explained variance on the axis, a decreasing trend can be seen. To interpret the canonical correlation, a couple of axes, the variance of which can be explained with the highest percentage should be chosen. In the study, the F1 and F2 axes which together explained 75 to 85% of the variance were considered. The F1

Table 2. Normality test.

Bartlett's sphericity test	
Chi-square (Observed value)	1041.414
Chi-square (Critical value)	24.996
DF	15
One-tailed p-value	< 0.0001
Alpha	0.05

Table 3. Eigenvalues for tree species.

Tree specie		F1	F2
Oak	Eigenvalue	3.116	1.411
	Cumulative (%)	51.937	75.459
Beech	Eigenvalue	3.291	1.657
	Cumulative (%)	54.858	82.474
Hornbeam	Eigenvalue	3.778	1.351
	Cumulative (%)	62.971	85.481
Chestnut	Eigenvalue	3.825	1.190
	Cumulative (%)	63.752	83.579

Table 4. Squared cosines of the variables.

Tree specie	Oak		Beech		Hornbeam		Chestnut	
Parameters	F1	F2	F1	F2	F1	F2	F1	F2
Saturated soil water	0.058	0.858	0.040	0.395	0.081	0.854	0.000	0.977
Droughty day in upper soil zone	0.720	0.014	0.572	0.207	0.715	0.007	0.816	0.005
Droughty day in all soil zone	0.840	0.024	0.898	0.039	0.872	0.006	0.895	0.000
Average root depth	0.422	0.052	0.561	0.330	0.745	0.002	0.502	0.148
Average soil depth	0.187	0.437	0.329	0.629	0.435	0.459	0.718	0.059
Droughty of root zone	0.889	0.027	0.891	0.058	0.930	0.023	0.895	0.000

and F2 axes represent the hydrological variables and the population scores of the tree species considered by the canonical correlation analysis. In interpreting the canonical functions that were gathered (Table 4), the size or sign (positive/ negative) of the canonical coefficients represent the position of the variable on the axis (Figure 1). The interpretation, as seen as follows can be stated according to the positions of the variables. The first ordination was generated from the data from the 166 sample areas with slightly mixed stands. It has been shown that the parameters of the four tree species affect each other when regression techniques are used and this impacts the accuracy of the results. To avoid this negative effect, the analyses of the tree species were carried out separately. The size and position of the canonical coefficients on the axis are shown in Figure 1. When all 437 sample areas were subjected to canonical analyses, the relationship between the habitat and the tree species decreased to the point that interpretation was not possible. The reason for this is the accumulation of the symbols of tree species in certain areas and thus channeling is unclear. This shortcoming was overcome in the histogram (Figure 2) which shows the hydrological regime of the soil groups in pure and mixed dominant tree stands.

In Figure 4, a meso-combinational map of the distribution of tree species in the studied region is presented. The map provides a visual-spatial picture of the forest to aid the discussion of the results.

Just after it, the general visual plan presents the map of the "days of drought in the root zone" (middle) and the upper soil zone (right).

Table 5. Correlation matrices of trees (r^2).

Factor	Saturated soil water	Droughty day in upper soil zone	Droughty day in all soil zone	Average root depth	Average soil depth	Droughty of root zone
Oak						
Saturated soil water	**1**					
Droughty day in upper soil zone	0.025	**1**				
Droughty day in all soil zone	0.046	**0.818**	**1**			
Average root depth	**-0.446**	**-0.304**	**-0.346**	**1**		
Average soil depth	**0.356**	**-0.220**	**-0.361**	**0.478**	**1**	
Droughty of root zone	**0.330**	**0.792**	**0.904**	**-0.515**	-0.184	**1**
Beech						
Saturated soil water	**1**					
Droughty day in upper soil zone	0.233	**1**				
Droughty day in all soil zone	0.186	**0.785**	**1**			
Average root depth	-0.022	-0.220	**-0.540**	**1**		
Average soil depth	0.276	-0.078	-0.346	**0.917**	**1**	
Droughty of root zone	0.265	**0.776**	**0.994**	**-0.537**	-0.313	**1**
Hornbeam						
Saturated soil water	**1**					
Droughty day in upper soil zone	0.225	**1**				
Droughty day in all soil zone	0.139	**0.813**	**1**			
Average root depth	**-0.389**	**-0.558**	**-0.660**	**1**		
Average soil depth	0.356	**-0.390**	**-0.581**	**0.681**	**1**	
Droughty of root zone	0.385	**0.815**	**0.950**	**-0.777**	**-0.490**	**1**
Chestnut						
Saturated soil water	**1**					
Droughty day in upper soil zone	-0.056	**1**				
Droughty day in all soil zone	0.050	**0.882**	**1**			
Average root depth	-0.297	-0.509	-0.482	**1**		
Average soil depth	0.286	**-0.616**	**-0.694**	**0.742**	**1**	
Droughty of root	0.050	**0.882**	**1.000**	-0.482	**-0.694**	**1**

In bold, significant values (except diagonal) at the level of significance alpha = 0.050 (two-tailed test).

DISCUSSION

Upon the examination of Figure 1, inferences can be made about the relationships between the species from the 1st and 2nd axis, and the water quantity and quality parameters can be obtained. The position of the arrows belonging to the hydrological parameter and the tree species, and the eigenvalues of the axis indicate the intracluster relationship of the hydrological parameter and the tree species with the axis. On the F1 axis, the population of oak trees was observed to increase as decreases were observed in the amount of drought in the root zone (sc: 0.889), days of drought in all soil zones (sc: 0.840) and days of drought in the upper soil zone (sc: 0.720). However, on the F2 axis, the population of Oak trees was observed to increase with the amount of saturated soil water (sc: 0.858). On the F1 axis, the population of Beech trees was observed to increase as decreases were noted in the number of days of drought in all soil zones (sc: 0.898) and the amount of drought in the root zone (sc:0.891). It is known that beech does not tolerate stagnant high ground-water. However, less of this type of clustering is seen by low eigenvalue on this factor. The reasons for the presence of beech in these soil conditions are explained as follows. On the F1 axis, the population of hornbeam trees was observed to increase with the average root depth (sc: 0.745) and with a decreased amount of drought in the root zone (sc: 0.930), days of drought in all soil zones (sc: 0.872), days of drought in the upper soil zone (sc: 0.719) and saturated soil water (stagnant high ground-water: 0.854 on the F2 axis) (Figure 1). Environmental plasticity can be observed in Figure 1. Although, the contrasts with the distribution are insufficient, the ecological plasticity of the

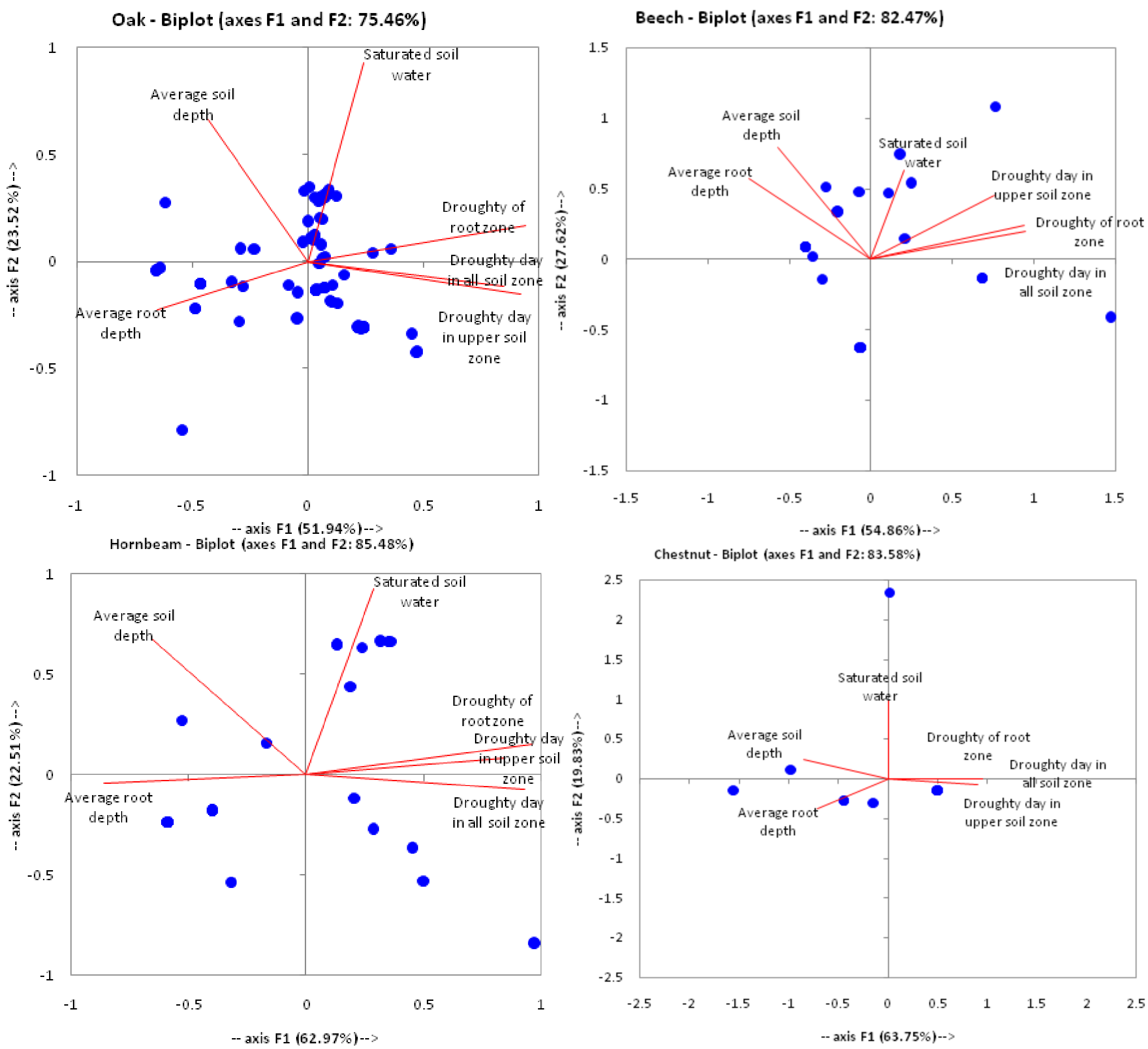

Figure 1. The ordination analysis of trees and the ecological plasticity as given by CCA.

individual species may be different. Oak does not show clear drains, but forms groups that are oriented to the hydrological properties of the soils. The orientation axis is the most clear; it is associated with drought in all soil layers and with “stagnant groundwater". Hornbeam is not channeled, and in contrast to oak, it does not form oriented groups, although obviously, hornbeam avoids any soil drought and tolerates stagnant waters relatively well.

The chestnut has a similar distribution and also appears to avoid soil drought. Figure 1 provides a visualization based on the preferences of the studied tree species. Such channeling of tree species provides specific requirements for optimal habitats and a wingspan of natural tolerance to deviations from the optimum. However, here, this "natural scale" refers only to the competitiveness and the ability to generate sustainable clean plantations. In fact, oak, chestnut and hornbeam are species with high ecological plasticity. Beech is very limited in this respect. The histogram (Figure 2) shows that the best hydro-regime groups are the pure beech stands B (a, b, c) and B (cd, d, e). In these groups, beech is in its optimum within the studied region and competition from other tree species is avoided. As the involvement of other tree species increases, B + ≤ 30% b, c; B + ≥ 30% b, c; B + 40% cd, d; and B + ≥ 30% c, d, the number of dry days in all soil zones and root formation depth slightly increase. However, none of these falls in

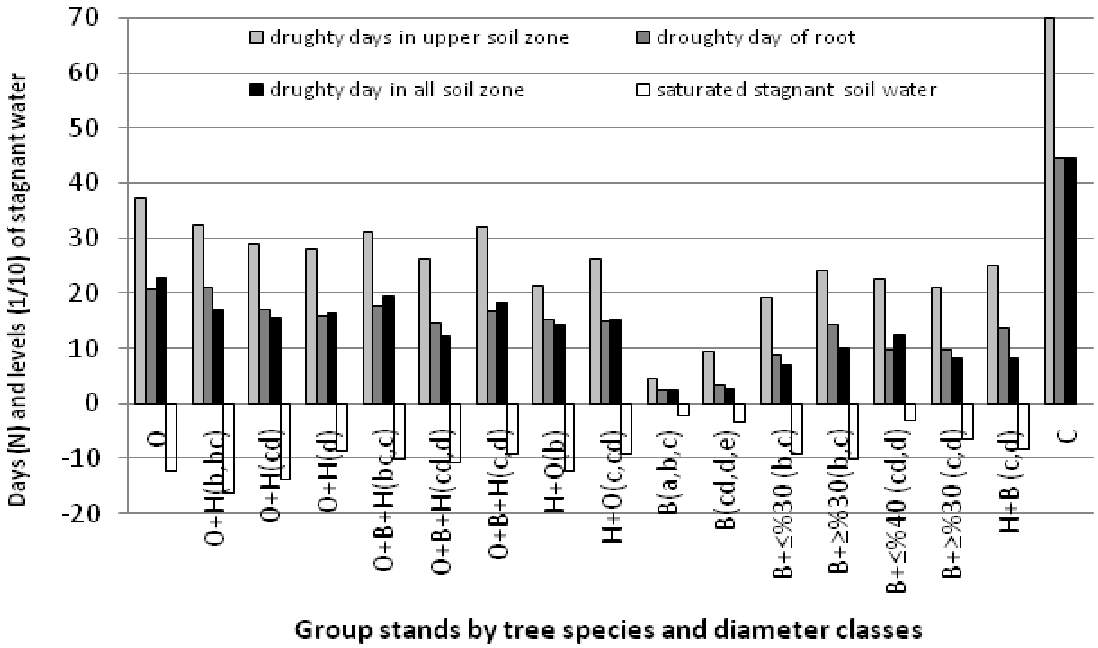

Figure 2. Number of droughty days of the soil horizons and levels of saturated (stagnant) soil water of stands grouped by tree species and average diameter (O - oak, B - beech, H - hornbeam, C - chestnut).

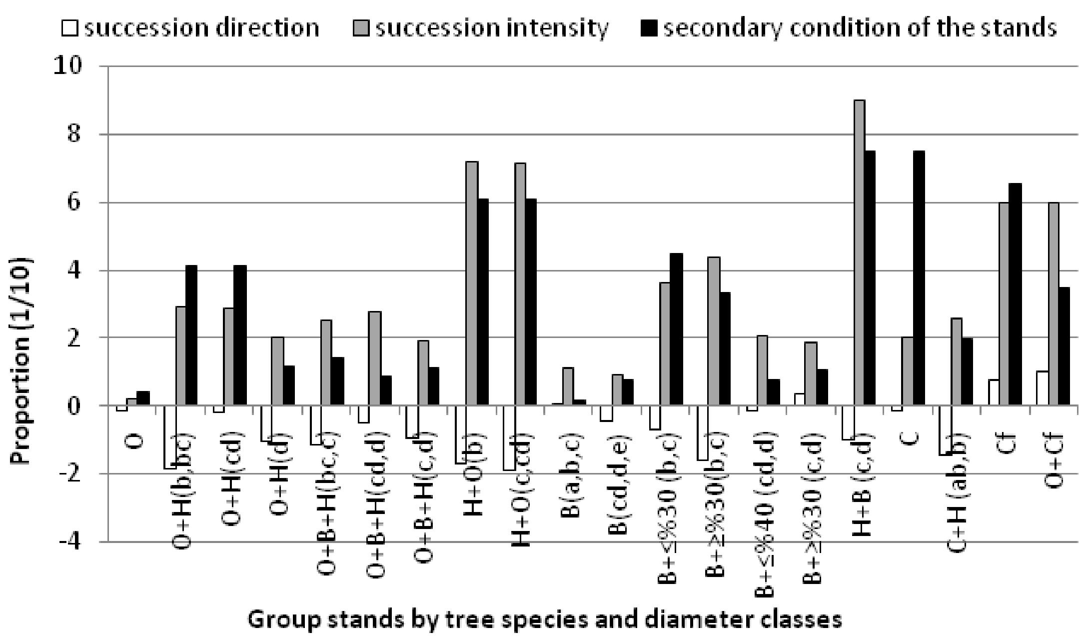

Figure 3. Succession processes and primary condition of the stands grouped by tree species and average diameter (O - oak, B - beech, H - hornbeam, C - chestnut, Cf - conifers).

the critical rate of hydrological drought over the duration of ≥ 23 days. The factors "stagnant groundwater" and "days of drought in the upper soil zone" also increase with the occurrence of other species. However, it appears that the adult mixed beech stands factor "stagnant groundwater" is almost absent. In all pure oak and hornbeam mixed with young oak stands (O; O + H b,bc), "days of drought in all soil zones" and "days of drought in the root zone" are adjacent to the critical rate of "hydrological drought". In contrast, in older "O + H (cd) and O + H (d)", these indicators are lower. The same is also true in mixed beech and hornbeam oak stands.

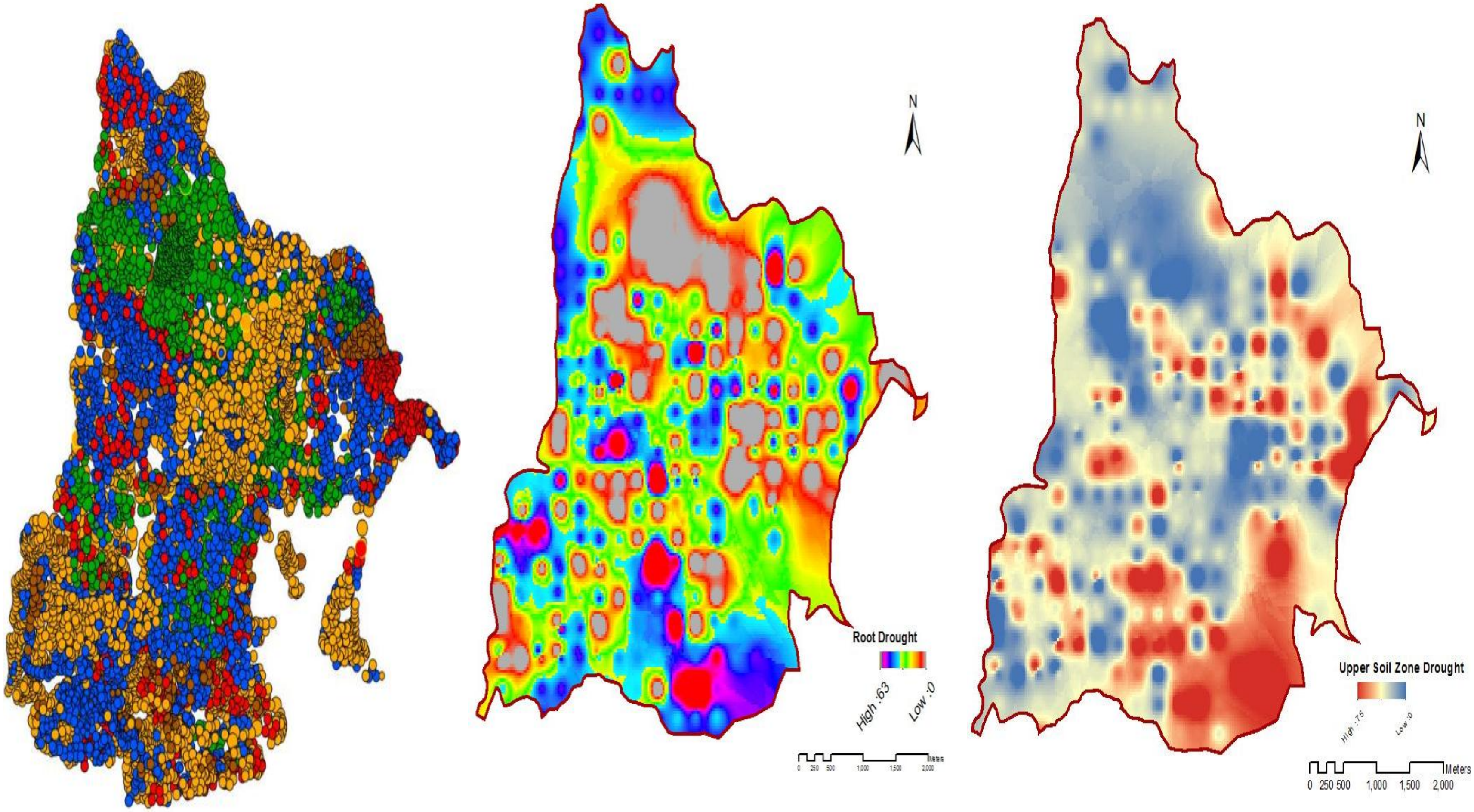

Figure 4. Spread of tree species in the study area with colours: oak – yellow; eastern beech – green; hornbeam – blue; chestnut – red; other deciduous – brown, each circle is equal to the estimated number of trees - 50 to 70 and map soil moisture deficiency in the plant root and upper soil zones the growing season.

However, in all groups, "days of drought in the upper soil zone" is significant. Groups dominated by hornbeam have nearly identical performance to those with older oak with hornbeam. The most expressive indicator is chestnut, and this tension is high. "Days of drought in all soil zones" and "days of drought in the root zone" exceed almost twice the minimum threshold of "hydrological drought". The topsoil is dry throughout the summer season. For both young (B a, b, c) and adult (B cd, d) pure stands of beech, successional processes are hardly observed (Figure 3). These processes are important in young and middle-aged (B + ≤ 30% b, c and B + ≥30% b, c) mixed stands. In older mixed stands (B + ≤ 40% cd, d and B + ≥ 40% c, d), these values were lower, and they do not exist in pure oak plantations (O) of any age. However, mixed stands with hornbeam succession are negative, with considerable intensity and high secondary. With the participation of beech in the mixture, the indicator "secondary" is significantly reduced, but the intensity of succession remains significant. The high and secondary intensity indicators contain stands dominated by hornbeam (H + O b; H + O c, cd; H + B c, d). This succession is negative and has a significant involvement of oak in the mix. The intensity of succession in pure chestnut stands (C) is lower, but the proportional indicator "secondary" is very high. When mixed with hornbeam, young chestnut trees (C + H ab, b) are relatively low, but apparently intensive of succession. The introduced pine stands (Cf; O + Cf) run a positive succession of high intensity. The indicator "secondary" is a low proportional value in mixed oak stands. Figure 1 shows that oak covers a wide range of soil conditions away from the center of the coordinate system, symbolizing optimal survey site soil conditions. Oak cannot create pure stands and shares habitat with competing species (Radkov, 1963, 1970; Delkov 1988). Pure oak stands are unbearable for other tree species' soil condition requirements - a combination of drought and soil stagnant groundwater.

The reason for this is because the "days of drought in the root zone" (20.5 days) and "days of drought in all soil zones" (23 days) border "hydrological drought". Here, "days of drought in all soil zones" is a more common measure of "days of drought in the root zone". These measurements are derived from 93 sample plots representing different soil conditions. Provided that the "days of drought in all soil zones" falls below 20 days, hornbeam and beech begin to participate in plantations. In fresh, deep and medium deep soils, airy eastern beech forms pure stands with no shrub layer. A lack of hornbeam is due to a reaction to the acidity of the “Ah” soil horizon, which does not bear the seeds of this species. However, with the increased occurrence of oak, this acidity disappears and hornbeam can participate in the mixture (Radkov, 1963, 1970; Delkov, 1988; Destan, 2001). In the past, beech wood was of non-commercial value. Other tree species have been subject to intensive and uncontrolled logging. Therefore, the spread of beech was unimpeded. As shown in the figure, parts of beech trees are found in soils with high stagnant groundwater. This fact was discovered by both Eruz (1980) and Kantarci (1980). Kantarci (1980) found that 19% of the total area inhabited by beech has soil with poor drainage. Destan (2001) specified that, in an area of 18.2% oak, improved soil drainage was observed with increasing age of plantation. The position of hornbeam in the soil and hydrological parameters resembled that of beech, albeit a little worse. It should be noted that hornbeam is extremely resistant to stagnant waters. It is also noteworthy that hornbeam can participate in almost any mixture of trees (Radkov, 1970; Kantarci, 1980; Destan, 2001). This has given rise to Yonelli (1986) to put him in high *syntaxonomic* rank "*Q. petrea* ssp. *Iberika – C. betulus*" forest association. This is due to perceptions in the selection of diagnostic elements in the convent attached inductive. However, despite his great amount of use as the main edificatory, hornbeam along with oak, would mislead the investigation of the possible ‘euklimax autogen’ process. In this context, it can be argued that the hornbeam is not a major forest-forming tree species; it is only a major accompanying tree species.

Chestnut is of the main species in these forests. In the past, chestnut was the main forest-forming species. Yonelli’s research (1986) classified the available and potential forests of chestnut in the sub-rank "typical *C. sativa*". On this basis, Kantarci (1980) classified them as a "transitional *Castanetum-Fagetum* zone, with bias to the chestnuts." However, the distributions of chestnut across soil conditions do not fit these requirements because of a very intensive and uncontrolled exploitation that began in the Byzantine period. Chestnut wood was valuable for the construction of vessels, and fruits were a part of the traditional menu in the kitchens of the local population. As a result, chestnut gradually disappeared from the area of optimal habitat and took positions on the ridges (54%) and on the upper and middle slopes (34%). Today, many of these trees are of coppice origin. Their ability to withstand soil drought is a result of their older roots drawing water from penetrations deep into the soil-forming material (Delkov, 1988; Kantarci, 1980; Destan, 2001). Despite a few exceptions, it appears that mature stands decrease the number of physiologic dry days and lower the level of stagnant groundwater because the small number of trees per unit area results in a low leaf area, decreased interception and transpiration, a thick rug of dead leaves, higher infiltration, lower surface runoff and more. Although, indirect, these findings confirm the studies of Destan (2011) and İnan and Destan (2011). These studies found that, with increasing age, the efficient water supply to the plantations (*Q. petrea* Liebl. and *Q. fraineto* Ten.) of oriental beech increased from 150 to 270 mm. Thus, to improve the hydro-physical properties of soil, it is imperative to maintain the average age of forests as old. The studies conducted by Akkemik et al. (2006) on the radial increment of the Belgrade Forest showed that almost 90% of the annual ring’s width is formed in May to June, with the remaining 10% forming by the end of July. This means that physiological transpiration (which is related to biomass production) almost ceases at the beginning of July and continues only during the warm months. During prolonged soil drought, Yaltirik (1966) and Çepel (1971) rightly suggested that trees compensate for the lack of moisture with horizontal precipitation (fog, dew, etc.).

The average size of sample plots is 400 m^2 = 0.04 ha. The intensity of the inventory to correct for systematic (300 × 300 m) sampling is [(472 * 0.04) / 2622)] * 100 = 0.72%. The ordination between the main tree species and the hydro-physical properties of soil for pure stands was established and the intensity of the sample was only

0.06%. The ordination between the main tree species and the hydro-physical properties of the soil for mixed stands used a sample intensity of 0.23%. A visual comparison of figures shows high similarity and parallelism between the spatial distributions of tree species, the distribution of soil drought at the area of the site and the presence and intensity of apparent succession and others. Even this low-intensity inventory reveals a clear picture of the relationship between the soil and the trees.

REFERENCES

Abrams MD, Scott, ML (1989). Disturbance-Mediated Accelerated Succession in Two Michigan Forest Types. Forest Sci., 35(1) 42-49.

Akkemik U, Çinar-Yilmaz H, Sevgi O (2006). Cambial activity of *Quercus petraea* (Mattuscha) Liebl. in Belgrade Forest (Istanbul). Turkish J. Agric. For., 30: 429-438 (In Turkish).

Bord RJ, O'Connor RE (1997). The gender gap in environmental attitudes: the case of perceived vulnerability to risk: research on the environment, Publisher: Blackwell,. Soc. Sci. Q., 78(4): 830–840.

Çepel N (1971). Influence of forest vegetation on rainfall reached the soil and the results of 5 year studies at the Belgrade forest. Review of the Faculty of Forestry, Istanbul University. Series 2/B, 54-59, Number 21 (In Turkish).

Delkov N (1998). Dendrology. Zemizdat – Sofia, second edition, p. 173 (In Bulgarian).

Destan S (2001). Management and Functional Characteristics and Assessment of Forest Ecosystems in Forest Management Activities. Ph.D. Thesis, Faculty of Forestry, Forestry University-Sofia. (In Bulgarian).

Destan S (2011). A conceptual model of forest stand hydrologic effect: potential application in the forest management practice. Afr. J. Agric. Res., 6(14): 3432-3444 (In Bulgarian).

Fosaa AM, Sykes MT, Lawesson JE, Gaard M (2004). Potential effects of climate change on plant species in the Faroe Islands. Global Ecol. Biogeogr., 13: 427–437.

Gustafson EJ, Shifley SR, Mladenoff DJ, Nimerfro KK, He HS (2000). Spatial simulation of forest succession and timber harvesting using LANDIS. Cana. J. For. Res., 30(1): 32-43.

Jongman RHG, ter Braak CJF, van Tongeren OFR (1987). Data analysis in community and landscape ecology. Pudoc, Wageningen, p. 299.

Liu J, Ashton PS (1995). Individual-based simulation models for forest succession and management. For. Ecol. Manage., pp. 157-175.

Kantarci MD (1980). Survey and Mapping of Soil Types and Forest Habitats in Belgrade Forest Located North of Istanbul. Istanbul University, Faculty of Forestry, Publisher № 2636/275 (In Turkish).

İnan M, Destan S (2011). GIS-Based Hypothetic Water Budget Models and Its Potential Use in Temperate Zone Forest Towards Water Production Objective. Managed Forests in Future Landscapes - Implications for Water and Carbon Cycles, Santiago de Compestela, Spain May 8-11, 2011. Page: 166.

Isaev AS, Abaimov AP, Buzikin AI, Efremov SP, Nazimova DI, Petrenko ES, Semechkin IV (2005). Forest Biogeocenology - part of Forestry. Forestry, 4: 4-11 (In Russian).

Lehmann A, Overton JMcC, Leathwick JR (2002). GRASP: generalized regression analysis and spatial prediction. Ecol. Modell., 157, Issues 2-3, 30 November 2002, Pages.

Kenderes K, Mihók B, Standovár T (2007). Thirty years of gap dynamics189-207. In a central European beech forest reserve. Forestry, 81(1): 111-123.

Pavlov DP (1998). Phytoceonotic Basics of the Forest Typology in Bulgaria. Science Dissertation, University of Forestry in Sofia. (In Bulgarian).

Rozenbergar D, Stjepan M, Igor A, Juris D (2006). Gap regeneration patterns in relationship to light heterogeneity in two old-growth beech–fir forest reserves in South East Europe. Forestry, 80(4): 431-443.

Radkov IN (1963). Forest Formations and Forest Types in Bulgaria. Zemizdat, Sofia (In Bulgarian).

Radkov IN (1970). Ecological foundations of forestry. Zemizdat, Sofia, p. 201 (In Bulgarian).

Shugard HH (1984). A Theory of Forest Dynamics: The Ecological Implications of Forest Succession Models. Publishing; Ecology and Environmental Science, 278 pages.

St-Denis A, Kneeshaw D, Bergeron Y (2010). The role of gaps and tree regeneration in the transition from dense to open black spruce stands, Forest Ecology and Management , 259(2010): 469–476.

Taylor AR, Chen, HYH, Van Damme L (2009). A Review of Forest Succession Models and Their Suitability for Forest Management Planning. For. Sci., 55(1): 23-36.

Tabari M, Fayaz P, Espahbodi K, Staelens J, Nachtergale L (2005). Response of oriental beech (*Fagus orientalis* Lipsky) seedlings to canopy gap size. Forestry, 78(4): 443-450.

Tekin M (1993). Canonical Correlation Analysis and an Application. Ph.D. Thesis, Institute of Sociology (In Turkish).

Tejedor M, Jiménez C, Monteverde C, Parra J (2004). The Influence of Deforestation on Soil Water Conservation in a Pine Forest in Tenerife (Canary Islands, Spain), ISCO 2004 - 13th International Soil Conservation Organisation Conference – Brisbane, July 2004.

Ter Braak CJF (1989). CANOCO - an extension of DECORANA to analyze species-environment relationships. *Hydrobiologia* 184: 169-170.

Ter Braak CJF, Prentice IC (1988). A theory of gradient analysis. Adv. Ecol. Res., 18: 271-317.

Tter Braak CJF, Šmilauer P (2002). CANOCO Reference Manual and Cano Draw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Ithaca, NY, USA (www.canoco.com): Microcomputer Power.

Tunçkale IH (1965). Studies of soil types and the spread of their Belgrade forest. Review of the Faculty of Forestry, Istanbul University, Series C, Volume 15, Number 1/a (In Turkish).

Wang XP, Tang ZY, Fang JY (2006). Climatic Control on Forests and Tree Species Distribution in the Forest Region of Northeast China. J. Int. Plant Biol., 48(7): 778−789.

West DC, Shugart HH, Botkin DB (1981). Forest succession. Concepts and application. Publisher; Springer-Verlag New York Inc. 517 page.

Yaltirik F (1966). Studies on the floristic analysis of the vegetation of Belgrade Forest and composition of main stand types. Ministry of Agriculture, General Directorate of Forestry № 436; Series № 4. (In Turkish).

Yonelli V (1986). Untying and Silvicultural Evaluation of forest communities in the Belgrade Forest. Ph.D. Thesis, Faculty of Forestry, Istanbul University (In Turkish).

Zhu Y, Kang M (2007). Application of ordination and GLM/GAM in the research of the relationship between plant species and environment. Chinese J. Ecolo., 2007-07.