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Statistical analysis to support conclusions is usually necessary. Statistical analyses must be conducted in accordance with international statistical reporting standards. Information on statistical analyses should be provided with a separate subheading under the Materials and Methods section and the statistical software that was used during the process must be specified.

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cations with a high citation potential are welcomed. These authors may even be invited by the journal. Reviews should describe, discuss, and evaluate the current level of knowledge of a topic in the field and should guide future studies. The main text of review articles should be begun with an Introduction section and finalized with a Conclusion section. The remaining parts can be named relevantly to the essence of the research. Please check Table 1 for the limitations for Review Articles.

Short Note: This type of manuscript present significant findings from tangential investigations that are offshoots from larger studies or from early results that will have to be confirmed through further study. The main text should be structured with Introduction, Materials and Methods, Results and Discussion, and Conclusion subheadings. Please check Table 1 for the limitations for Short Note.

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When a product, hardware, or software program is mentioned within the main text, product information, including the name of the product, the producer of the product, and city and the country of the company (including the state if in USA), should be provided in parentheses in the following format: "EC meter (Orion Star A212, Thermo Scientific, MA, USA)

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Limitations, drawbacks, and the shortcomings of original articles should be mentioned in the Discussion section before the conclusion paragraph.

References: While citing publications, preference should be given to the latest, most up-to-date publications. If an ahead-of-print publication is cited, the DOI number should be provided. Authors are responsible for the accuracy of references. In the main text of the manuscript, references should be cited by author's name and the publication year in parenthesis. When there are more than two authors, the first author should be listed followed by "et al." Please see below for examples:

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Journal Article: Heede, B.H., 1991. Response of a stream in disequilibrium to timber harvest. *Environmental Management* 15 (2): 251-255.

Books with a Single Author: Birkeland, P. W., 1984. Soils and Geomorphology. Oxford University Pres, New York.

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Symposium, Conference and Workshop Papers: Dahlgren, R. A., 1988. Effects of forest harvest on stream-water quality and nitrogen cycling in the Casper creek watershed. In: Proceedings of The Conference on Coastal Watersheds: The Casper Creek Story. May 6, Ukiah, California.

Daganzo, C., 1996. Two paradoxes of traffic flow on networks with physical queues. II.Symposium Ingenieria de los Transportes, Madrid, 22-24 May 1996, pp. 55-62.

Online Document (Web) Reference: FAO. 2006. Rural radio transmissions and rural youth in Mali. http://www.fao.org/sd/dim_kn1/kn1_060202_en.htm (Accessed: 27 February 2006).

Article by DOI: Asakawa, S., Yoshida, K., Yabe, K., 2004. Perceptions of urban stream corridors within the greenway system of Sapporo, Japan. *Landscape and Urban Planning*, in press doi:10.1016/S0169-2046(03)00158-0.

Thesis: Güner, H.T., 2016. The Miocene flores and vegetation of the Yatağan Basin, Western Anatolia. Unpublished Ph.D. Thesis, Istanbul University, Institute of Sciences, p. 185., Istanbul, Turkey.

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Accepted manuscripts are copy-edited for grammar, punctuation, and format. Once the publication process of a manuscript is completed, it is published online on the journal's webpage as first online publication before it is included in its scheduled issue. A PDF proof of the accepted manuscript is sent to the corresponding author and their publication approval is requested within 2 days of their receipt of the proof.

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CONTENTS

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Original Article

Vegetation establishment improves topsoil properties and enzyme activities in the dry Aral Sea Bed, Kazakhstan

Kazakistan'da kuruyan Aral Deniz Yatağında bitki örtüsü gelişiminin üst toprak özellikleri ve enzim aktivitelerini iyileştirmesi

Jiae An, Seongjun Kim, Hanna Chang, Asia Khamzina, Yowhan Son

Department of Environmental Science and Ecological Engineering, Graduate School, Korea University, Seoul 02841, Korea

ABSTRACT

Afforestation has been conducted for preventing desertification in the desiccated Aral Sea Bed. The present study aimed to investigate the changes in topsoil properties and enzyme activities owing to vegetation establishment. In August 2017, soils were sampled from degraded area devoid of vegetation (DA), areas afforested in 2002 (P1) and 2013 (P2), and naturally vegetated area (NA) in the northern part of the exposed Aral Sea Bed. Soil water content, pH, electrical conductivity, total N and organic C concentrations, exchangeable cation concentrations (K^+, Mg^{2+}, Ca^{2+}, and Na^+), available P (P_2O_5) concentration, cation exchange capacity, and enzyme activities (acid phosphate, N-acetyl-glucosaminidase, and β-glucosidase) were analyzed in the topsoil up to a depth of 10 cm. Soil water content, total N and organic C concentrations, K^+ and Mg^{2+} concentrations, and enzyme activities were higher in P1 and NA than in DA. Moreover, no significant difference was found between P1 and NA in soil water content, total N and organic C concentrations, and some of the exchangeable cation concentrations. Our findings indicate that vegetation establishment increased the soil organic matter which is strongly associated with soil water content, organic C concentration, and overall soil fertility. The effects of plantation on soil amelioration are similar to those of natural vegetation in the long-term (15 years). Moreover, soil enzyme activities increased with rise in soil water content and total N and organic C concentrations in both vegetated areas (P1 and NA).

Keywords: Aral Sea, desertification, enzyme activity, restoration, soil amelioration

ÖZ

Kurumuş olan Aral Denizi Yatağında çölleşmeyi önlemek amacıyla ağaçlandırma yapılmıştır. Bu çalışma vejetasyon (bitkilendirme) çalışmasına bağlı olarak yüzey toprağı ve enzim aktivitelerindeki değişiklikleri araştırmak amacıyla yapıldı. Ağustos 2017'de, vejetasyondan yoksun çorak alandan (DA), 2002 (P1) ve 2013 (P2) yıllarında ağaçlandırılmış alanlardan ve Aral Deniz Yatağının kuzey bölümündeki doğal bitki oluşumuna sahip alandan (NA) toprak numuneleri alındı. Toprağın su içeriği, pH, elektrik iletkenliği, total N ve organik C seviyeleri, değiştirilebilir katyon seviyeleri (K^+, Mg^{2+}, Ca^{2+},ve Na^+), mevcut P (P_2O_5) seviyesi, katyon değişim kapasiteleri ve enzim aktiviteleri (fosfat asit, N-asetilglukozaminidaz ve β-glukosidaz) yüzey toprağından 10 cm derinliğe kadar analiz edildi. Toprak su içeriği, total N ve organik C seviyeleri, K^+ ve Mg^{2+} seviyeleri ve enzim aktivitelerinin P1 ve NA örneklerinde DA'ya göre daha yüksek olduğu görüldü. Ayrıca P1 ve NA arasında topraktaki su içeriği, total N ve organik C seviyeleri ve bazı değiştirilebilir katyon seviyeleri açısından anlamlı bir fark bulunmadı. Bulgularımıza göre vejetasyon çalışması, toprak su içeriği, organik C seviyesi ve genel toprak verimliliği ile oldukça ilişkili olan toprak organik maddesini artırdı. Toprağın iyileştirilmesinde bitkilendirmenin etkileri uzun dönemde (15 yıl) doğal vejetasyonun etkileriyle benzerdir. Ayrıca, toprağın enzim aktiviteleri toprağın su içeriği ve total N ve organik C seviyelerindeki artışla P1 ve NA numunelerinde yükselmiştir.

Anahtar Kelimeler: Aral Denizi, çölleşme, enzim aktivitesi, restorasyon, toprağın iyileştirilmesi

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INTRODUCTION

Desiccation of Aral Sea is considered one of the world's most serious environmental disasters in the recent past (Micklin, 2014). Aral Sea was the world's fourth-largest inland water body in 1960, with an area of nearly 67,000 km^2 (Waltham and Sholji, 2001). However, diversion of the tributary rivers for large-scale irrigation for supporting the extensive cotton industry caused its depletion starting from the 1960s. Aral Sea split into two water bodies as northern Small Aral Sea and southern Large

Aral Sea by the late 1980s, and the area decreased to 11,000 km^2 in 2015 (Jin et al., 2017). The decreasing water level and the increasing salinity caused soil degradation, vegetation decline, and deterioration of rich and diverse shoreline ecosystems (Micklin, 2014). Furthermore, a large amount of salts affected the physical and chemical properties of soils which in turn affected plant growth and enzyme activities (Singh et al., 2012a).

Considering the pace and scale of the desertification in this region, vegetation establishment is regarded as a more appropriate approach for reducing the associated damage from soil salinization and salty dust storms than e.g. chemical methods (Salt et al., 1998; Van et al., 2005; Park et al., 2013). Although naturally vegetated regions are present, establishment of vegetation by natural processes takes a long time. Rehabilitation of the dried seabed through afforestation has been attempted in several restoration projects (Micklin, 2014) aiming to reduce soil erosion, thereby increasing nutrient concentration and soil organic matter and improving soil structure (Shirato et al., 2004; Yüksek and Yüksek, 2011). Nonetheless, time for soil amelioration and extent of the effects through afforestation varied (Shirato et al., 2004; Singh et al., 2012b; Zhang et al., 2013); therefore, the degree of soil recovery following afforestation should be monitored and evaluated (Shirato et al., 2004).

Detecting soil properties and enzyme activities can be relevant for understanding biological processes in soil recovery. The interactions between physical and chemical properties of soils and exchangeable cations affect plant growth by controlling nutrient availability. In addition, they contribute to the increase in soil fertility and creation of supportive microenvironments for plants and microorganisms (Zhang et al., 2013). The increase in concentrations of nutrients such as P, N, and organic C are good indicators of soil quality and productivity because they affect the physicochemical and biological properties of soil (Cao et al., 2011). Furthermore, soil enzymes play an important role in organic matter decomposition and nutrient cycling (Cao et al., 2011). Enzyme activities are highly sensitive to the changes derived from plantations of different species and management practices on degraded lands (Singh et al., 2012a). Therefore, soil enzyme activities are considered to be useful indicators of soil ecosystem function, including microbial functioning, fertility, biological diversity, productivity, resource requirements, and nutrient availability to plants (Caldwell, 2005; Sinsabaugh et al., 2009). Therefore, the simultaneous measurement of soil properties and enzyme activities are required for evaluating the effect of plants on soil biochemical processes. Moreover, the vegetation establishment contributes to the increase in soil water content and fertility, decrease in pH and electric conductivity, and induced changes in microbial activities (Singh et al., 2012a).

The present study aimed to investigate the effects of the vegetation establishment on soil properties and enzyme activities in Aral Sea Bed. To this end, we compared soil biochemical properties in a degraded area with afforested and naturally vegetated area. Thereafter, the soil in the afforested area was compared with that in the naturally vegetated area to specify the differences associated with the type of vegetation establishment.

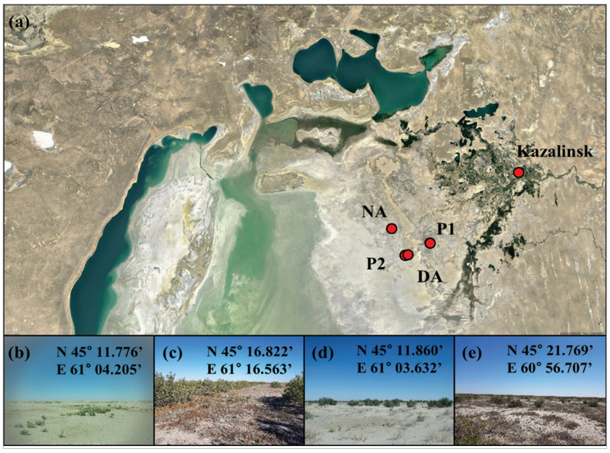

Figure 1. a-d. Location of the study area (a) and the photographs and GPS coordinates of study sites (b: degraded area (DA), c: area afforested in 2002 (P1), d: area afforested in 2013 (P2), and e: natural vegetation area (NA))

We hypothesized that (1) vegetation establishment ameliorates soils by reducing soil pH and salinity and enriching its fertility, (2) enzyme activities would increase after the vegetation establishment on degraded soil, and (3) the ameliorating effects on topsoil properties and enzyme activities differ between afforested and naturally vegetated areas.

MATERIALS AND METHODS

Study Area

The research area is located on the southwest of Kazalinsk (Figure 1) near northern Aral Sea. Four soil sampling sites were selected, i.e. degraded area (DA), without plant cover; plantation areas P1 and P2, where afforestation was carried out in 2002 and 2013, respectively; and a natural vegetation area (NA). Aral Sea shoreline has receded starting from 1970s in all the sites. The annual mean temperature of Kazalinsk is 7.5°C (Issanova and Abuduwaili, 2017), and the annual rainfall is less than 90 mm (Waltham and Sholji, 2001). Soil of the exposed bed of Aral Sea is dominated by solonchak and takyr (Breckle and Geldyeva, 2012) which are types of gray-brown desert soil characterized by high quantity of carbonates, low organic carbon content, and the presence of a superficial porous crust (Pachikin et al., 2014). The sampled soils were dominated by coarse sandy texture.

Soil Sampling and Analyses

After removing surface residues, soil samples were collected using a digging knife from three points at depths of 0-10 cm, and mixed in each of the four sites in August 2017. Soil water content was measured gravimetrically, after oven-drying fresh soil samples at 105°C. The samples were air-dried at room temperature and passed through a sieve to remove sea shells prior to the analysis of soil chemical characteristics. Soil pH was measured using a refillable pH electrode (ROSS Ultra pH/ ATC Triode, Thermo Scientific, MA, USA) in a 1:5 soil-to-distilled water mixture with shaking for 1 hour. Electric conductivity ($EC_{1:5}$) was measured by EC meter (Orion Star A212, Thermo Scientific, MA, USA), after shaking the 1:5 soil-to-distilled water mixture for 30 minutes. Total N concentration was determined by dry combustion at 1,000°C with an elemental analyzer (vario Macro, Elementar Analysensysteme GmbH, Langenselbold, Germany), and the soil organic C concentration was measured by the Walkley and Black wet digestion and titration method (Walkley and Black, 1934). Soil concentration of exchangeable cations (K^+, Mg^{2+}, Ca^{2+}, and Na^+) and available P (P_2O_5) were measured using ICP-OES (730 series, Agilent Technologies Inc., CA, USA) after Mehlich 3 extraction. Cation exchange capacity (CEC) was calculated by adding up the total amount of exchangeable K^+, Mg^{2+}, Ca^{2+}, and Na^+ measured.

Three enzyme activities in soil (acid phosphate (AP), N-acetyl-glucosaminidase (NAG), and β-glucosidase (BG)) were used to represent the degradation of main soil biochemical compounds (Table 1) (Sinsabaugh et al., 2009). These enzymes were measured by fluorometric method (DeForest, 2009) in black polystyrene 96-well microplates (300 μL, SPL Life Sciences Co. Ltd, Pocheon-si, Korea), using substrate analogs linked to the fluorescent molecules of 4-methylumbelliferon (4-MUB, Sigma-Aldrich Co. Ltd, Yongin-si, Korea). For enzyme assays, soil suspension was prepared with 2 g soil and 100 mL of the Tris buffer (pH 8.0). The other procedures followed DeForest (2009), who used a strict order to incorporate the soil suspension, references, and substrates into the microplates. The microplates were coved and incubated at 25°C in the incubator for 4 hours. To terminate the reaction, 50 μL of 0.2 mol L^{-1} NaOH solution was added to each well. Fluorescence was measured at 355 nm excitation and 460 nm emission levels with a Multi-Detection Microplate Reader (Sense, HIDEX, Turku, Finland).

Statistical Analysis

One-way ANOVA was used for assessing the differences in soil water content, pH, $EC_{1:5}$, total N and soil organic C concentrations, concentrations of exchangeable cations and available P, CEC, and enzymes activities among the sites. Duncan's test was applied to indicate significantly different means ($p<0.05$). All statistical analyses were performed using SAS 9.4 (SAS Institute, NC, USA).

RESULTS AND DISCUSSION

P1 and NA had higher soil water content (% of weight) (DA: 2.46, P1: 6.93, and NA: 5.61; p=0.0021), total N and soil organic C concentrations (%) (DA: 0.01, P1: 0.05, and NA: 0.03; p=0.0010 and DA: 0.14, P1: 0.48, and NA: 0.38; p=0.0041, respectively), and K^+ and Mg^{2+} concentrations ($cmol_c$ kg^{-1}) (DA: 0.71, P1: 1.49, and NA: 1.65; p=0.0005 and DA: 7.51, P1: 9.61, and NA: 11.03; p=0.0097, respectively) than those of DA (Table 2). CEC ($cmol_c$ kg^{-1}) was

Table 1. Soil enzymes assayed for activity with abbreviation and substrate, corresponding Sigma-Aldrich product number (Sigma no.), related elements, and enzyme functions

Enzyme (Abbreviation)	Substrate	Sigma no.	Related element	Enzyme function
Acid phosphate (AP)	4-MUB-phosphate	M8883	P	Hydrolysis of phosphate from phosphosaccharides and phospholipids
N-acetyl-glucosaminidase (NAG)	4-MUB-N-acetyl-β-glucosaminide	M2133	N	Hydrolysis of chitin N-acetyl-β-glucosaminide
β-glucosidase (BG)	4-MUB-β-D-glucopyranoside	M3633	C	Hydrolysis of terminal β-D-glucosyl residues

Table 2. Soil properties of study sites

	Study site				
Soil properties	DA	P1	P2	NA	p
Soil water content (% of weight)	2.46 (0.69)^b	6.93 (1.70)^a	0.26 (0.07)^b	5.61 (0.68)^a	0.0021
pH	9.09 (0.10)	8.81 (0.04)	8.71 (0.04)	8.82 (0.13)	0.0835
EC1:5 (dS m^{-1})	13.62 (3.10)^{ab}	17.14 (3.57)^a	5.87 (1.41)^b	21.61 (4.06)^a	0.043
Total N (%)	0.01 (0.00)^b	0.05 (0.01)^a	0.01 (0.00)^b	0.03 (0.00)^a	0.0010
Organic C (%)	0.14 (0.01)^b	0.48 (0.11)^a	0.09 (0.00)^b	0.38 (0.04)^a	0.0041
K^+ (cmolc kg^{-1})	0.71 (0.10)^b	1.49 (0.16)^a	0.30 (0.03)^b	1.65 (0.24)^a	0.0005
Mg^{2+} (cmolc kg^{-1})	7.51 (0.53)^{bc}	9.61 (1.23)^{ab}	4.94 (0.26)^c	11.03 (1.38)^a	0.0097
Ca^{2+} (cmolc kg^{-1})	82.50 (11.26)	87.23 (1.21)	71.37 (4.43)	103.36 (2.60)	0.089
Na^+ (cmolc kg^{-1})	9.19 (2.15)	10.71 (2.63)	3.27 (0.33)	13.28 (6.16)	0.1654
Available P (P_2O_5) (ppm)	2.22 (0.74)^b	46.80 (17.52)^a	2.64 (0.18)^b	10.81 (1.58)^b	0.0359
CEC (cmolc kg^{-1})	99.92 (8.74)^{bc}	109.04 (5.18)^{ab}	79.87 (4.90)^c	129.32 (5.18)^a	0.0087

$EC_{1:5}$: electric conductivity, CEC: cation exchange capacity
Means (standard errors) with different letters within a variable indicate significant difference among study sites at $p<0.05$.

Table 3. Acid phosphatase (AP), N-acetyl-glucosaminidase (NAG), and β-glucosidase (BG) enzyme activities (nmol/h/g soil) in study sites

	Study site				
Enzyme	DA	P1	P2	NA	p
AP (nmol h^{-1} g^{-1} soil)	0.69 (0.25)^c	36.68 (6.32)^b	0.90 (0.29)^c	50.30 (2.83)^a	<0.0001
NAG (nmol h^{-1} g^{-1} soil)	0.00 (0.00)^b	12.13 (4.20)^a	0.08 (0.01)^b	8.07 (2.15)^a	0.015
BG (nmol h^{-1} g^{-1} soil)	0.00 (0.00)^b	49.84 (7.77)^a	0.78 (0.27)^b	63.18 (6.84)^a	<0.0001

Means (standard errors) with different letters within a variable indicate significant difference among study sites at p<0.05.

significantly higher in NA than in DA (DA: 99.92 and NA: 129.32; p=0.0087), and P_2O_5 concentration (ppm) was significantly higher in P1 than in the other sites (DA: 2.22, P1: 46.80, P2: 2.64, and NA: 10.81; P=0.0359). Soil pH did not differ significantly among the sites, all of which had alkaline soils (pH 8.71-9.09). No significant difference in $EC_{1:5}$ was found in P1, P2, and NA, as compared with DA. Analysis of the effect of vegetation establishment for different durations on enzyme activities (nmol h^{-1} g^{-1} soil) showed that AP (DA: 0.69, P1: 36.68, P2: 0.90, and NA: 50.30; P<0.0001), NAG (DA: 0.00, P1: 12.13, P2: 0.08, and NA: 8.07; p=0.015), and BG (DA: 0.00, P1: 49.84, P2: 0.78, and NA: 63.18; p<0.0001) were significantly higher in the vegetated areas (P1 and NA) than in the degraded area (DA), whereas the difference between DA and P2 was not significant (Table 3).

Consistent with the first hypothesis, our results combined point at an increase in soil nutrient because of long-term vegetation establishment, either naturally (since 1970s) or by afforestation (since 2002). Positive interaction of vegetation with soil water content has been observed previously (D'Odorico et al., 2007; Singh et al., 2012b). Soil water content could increase in vegetated areas owing to reduction in air and soil temperature and lower evaporation from the soil surface shaded by plants (Kizito et al., 2006). In contrast, soils in degraded area tend to dry out rapidly owing to the higher exposure to solar irradiance, which causes greater soil water evaporation (D'Odorico et al., 2007). In addition to the shading effect, vegetation may improve soil infiltration capacity owing to the action of roots (D'Odorico et al., 2007). However, soil water depletion has been reported in the case of large-scale afforestation in drylands (Jackson et al., 2005).

In addition, enrichment of fertility is a well-known indicator of soil amelioration (Singh et al., 2012b). The superior total N and organic C concentrations in P1 than in DA might be due to foliar litter inputs, fine root turnover (Singh et al., 2012b), and formation of humus (Jobbágy and Jackson, 2004). Exchangeable cation concentration in the study sites tended to differ according to the type of cation. A previous study on coastal sand dunes reported a higher concentration of K^+ in the topsoil of afforested areas, whereas that of Na^+ did not change because of the differential importance of cations for plants (Jobbágy and Jackson, 2004). Exchangeable K^+ is known to accumulate in surface soils because of upward transport by plants and plant litter decomposition (Jobbágy and Jackson, 2001).

Reduction of pH by natural or artificial vegetation establishment, as reported in studies on amelioration of sodic soils (Singh et al., 2012b) was not relevant in the present study on primary vegetation succession and afforestation in the Aral Sea Bed. In addition, the uptake of nutrient cations by roots requires the reverse flux of H^+, which could decrease the pH of soil in vegetated areas (Nilsson et al., 1982). However, the absolute amount of nutrients is very low in this region (Table 2). Therefore, longer time might be required for nutrient absorption and lowering of pH by vegetation. Several previous studies, which reported that the success of plantations in ameliorating saline-alkali land depends on the duration time of the plantation and the corresponding amount and quality of litter deposited (Singh et al., 1994; Singh et al., 2012b; Zhang et al., 2013). Particularly, a significant change in pH with plantation duration has been reported (Zhang et al., 2013). Shirato et al. (2004) has specified that approximately 20 years is needed for soil recovery because soil properties change slowly. Previous afforestation studies in Central Asia revealed either decrease (Hbirkou et al., 2011) or increase (Khamzina et al., 2016) in soil salinity following vegetation establishment. In the Aral Sea Bed, both, long-term vegetated and exposed areas exhibited high salinity, suggesting that abiotic factors such as groundwater oscillations might play a role in the soil salinity dynamics (Schachtsiek et al., 2014).

No statistically significant difference was found between P1 and NA for most of the soil properties studied, which indicates similarity in the state of amelioration in spite of the longer duration of plant cover in NA than in P1. Increasing soil organic C concentration during the vegetation restoration process is associated with the increase in soil CEC (Shirato et al., 2004). The variation in exchangeable cation concentrations and CEC would change along with soil chemical properties, such as pH, C and N concentrations, and biological properties, which affect the availability of nutrients to plants (Zhang et al., 2013).

Similar to the second hypothesis, increases in soil enzyme activities, which reflect that microbial activity in the soil, might be promoted by the plantation. Enzyme activities of soil are very early and sensitive indicators for changes during restoration (Cao et al., 2011), and they are affected by various soil properties, such as soil water content and nutrient supplements (Davidson and Janssens, 2006; Steinweg et al., 2013). Similarly, distinct correlations of enzyme activities with soil water content and total N and organic C concentrations in the present study (Figure 2). In-

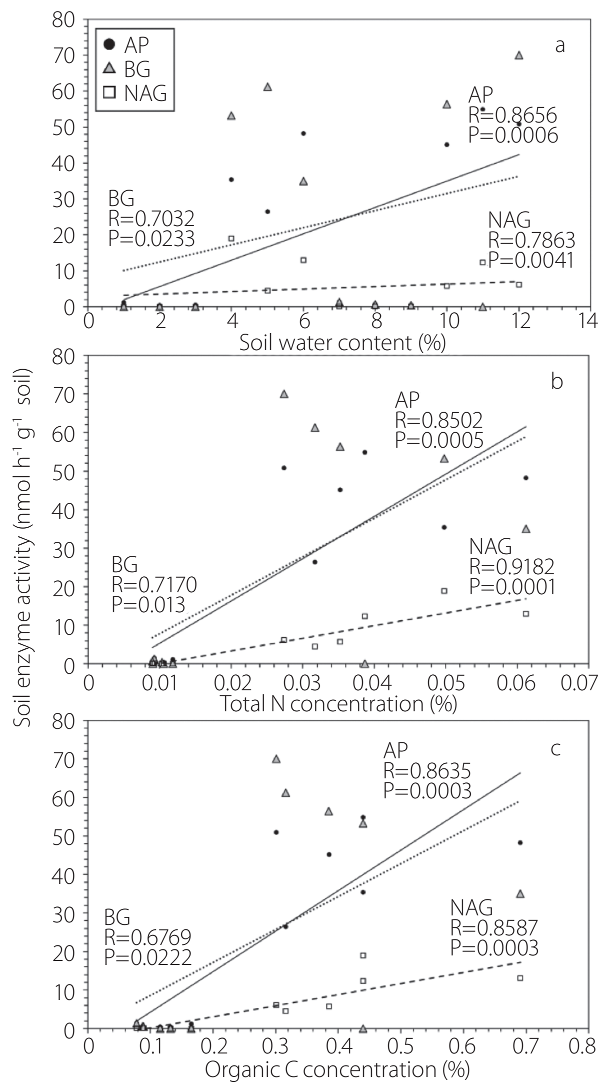

Figure 2. a-c. Correlations of enzyme activity (nmol h^{-1} g^{-1} soil) (Acid phosphatase (AP), N-acetyl-glucosaminidase (NAG), and β-glucosidase (BG)) and soil water content (a) and total N (b) and organic C concentrations (%) (c)

creases in soil organic C concentration and water content might be favorable for soil microbes, thereby promoting the secretion and activity of enzymes (Sileshi et al., 2007). However, enzyme production could be stimulated with increase in the diffusion of substrate or increase in bioavailability of nutrients in the soil (Davidson and Janssens, 2006; Steinweg et al., 2013). Even if nutrients available in soil were sufficient for microbial activity, available nutrient diffusion limitations in environments with low soil moisture content can reduce the production of microbial enzymes (Steinweg et al., 2013). Thus, enhanced microbial activity in vegetated areas can contribute to plant productivity through the regulation of mineral nutrient availability (Van Der Heijden et al., 2008).

Nevertheless, both positive and negative effects of plantation with soil water and salinity have been reported (Qi et al., 2015), whereas the results of the present study are based on the one-off, small-scale soil survey. Therefore, recurrent monitoring at larger spatial scales would be required for capturing the spatial heterogeneity in soil properties, which are dependent on vegetation distribution (Li et al., 2011), and the manifestation of the detailed effects of soil amelioration by vegetation establishment after plantation.

CONCLUSION

Distinct effects of vegetation establishment on soil chemical characteristics and microbial enzyme activities were found on the desiccated bed of Aral Sea. The changes were pronounced in P1, which was afforested in 2002, and in NA, which was naturally vegetated. However, no change was found in P2, the recently planted area (2013) as compared with the degraded area. Vegetation establishment increased soil organic matter, soil organic C concentration, and soil water content. These changes might have been responsible for the increase in CEC and nutrient retention capacity, resulting in increases in K^+ and Mg^{2+} concentrations. Improvements in soil properties, such as increases in soil water content, nutrient concentrations, and enzyme activities were comparable between P1 and NA. Evidently, plantation exerts similar amelioration effects as those exerted by natural vegetation, subject to the availability of sufficient time for vegetation development. Furthermore, afforestation appears to be quicker method that is as effective as natural vegetation establishment. Therefore, rehabilitation through plantation might be recommended for establishing soil cover and reinforcing the process of the natural succession.

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Original Article

Evaluation by prediction of the natural range shrinkage of *Quercus ilex* L. in eastern Algeria

Doğu Cezayir'de *Quercus ilex* L.'nin doğal yayılış alanında azalmanın öngörülmesinin değerlendirilmesi

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ABSTRACT

The aim of this study was to evaluate by prediction of the spatial distribution of *Quercus ilex* L. in its natural range in eastern Algeria. The maximum entropy method was used for modeling the species in potentially favorable areas under environmental conditions by linking the spatial occurrence and the environmental conditions. The following three explanatory parameter groups were used for the modeling: i) edaphic variables, ii) variables related to topography, and iii) climatic variables. The established predictions demonstrated that over the horizons 2050 and 2070, we shall lose 125,000 and 147,000 hectares, respectively. The most favorable areas for *Q. ilex* L. would appear to extend between the elevations of 1430 m by 2050 and reach 1650 m by 2070. The performance of the model used in this study was confirmed by the AUC (*area under the curve*) value of 0.929. The high elevations, especially those of the Saharan Atlas, would offer climatic refuges. These results represent a decision support tool for designing the best strategy of sensitization. and planning for the conservation of the holm oak.

Keywords: Climatic forcing, Ecological niche, Species distribution model, Holm Oak, Maximum entropy

ÖZ

Bu çalışma *Quercus ilex*. L'nin Doğu Cezayir'de doğal yayılışının mekansal dağılımının öngörülmesinin değerlendirilmesine odaklanmaktadır. Maksimum entropi yöntemi, mekansal oluşum ve çevre koşullarını ilişkilendiren çevresel şartlar altında potansiyel olarak uygun türleri modellemeye olanak sağlamıştır. Modelleme için üç açıklayıcı parametre grubu kullanıldı: i) edafik değişkenler, ii) topografya ile ilgili değişkenler ve iii) iklimsel değişkenler. Öngörülere göre, 2050 ve 2070 yıllarında sırasıyla 125000 ve 147000 hektar alan kaybolacaktır. *Quercus ilex* için en uygun alanlar 2050 yılında 1430 metre rakıma ve 2070'de 1650 metre rakıma çıkacaktır. Çalışmada kullanılan modelin performansı 0,929 olan AUC değeri ile doğrulandı. Yüksek rakımlar, özellikle Sahra Atlaslarının rakımları, iklime bağlı olarak sığınaklar sunacaktır. Bu sonuçlar en iyi sensibilizasyon stratejisi ve çalı meşesinin korunmasının planlaması için verilecek kararları destekleyecek bir araç niteliğindedir.

Anahtar Kelimeler: İklimsel uyarı, ekolojik konum, tür dağılım modeli, çalı meşesi, maksimum entropi

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INTRODUCTION

Climate change has important consequences on biocenosis dynamics, affecting the structure of the community. Process disturbances have been reported to change the distribution of species (Vitousek et al., 1997; Norby, 1998; Parmesan, 2006; Önder et al., 2009; Slimani et al., 2014). Assessing the future species distribution under the anticipated climate change is a very important topical challenge (Ahmed et al., 2015). Species modeling is an approach that allows linking the spatial and temporal variations of the environmental factors and their effects on the distribution of the species ecological niche (Thruiller, 2003; Guisan and Thruille, 2005; Çoban, 2016; Ray et al., 2017).

According to Lobry and Sari (2007), modeling permits the integration of statistical methods to describe phenomena by implementing equations in a computer model, which allows simulating the possibilities of unrolling the various phenomena to be described. For this purpose, several models have been implemented, including the widely used SDM model (*Species Distribution Model*) (Kumar et al., 2014; Warren et al., 2010; Warren and Seifert, 2011). This model permits the modeling of the potential distribution of the species (Austin, 2002; Reddy et al., 2015; Matawa F, 2016). Several statistical methods can be used to implement an SDM, including the GAM (generalized additive model) (Zuur et al., 2009), boosted regression trees (De'Ath., 2007), combinatorial optimization GARP (Genetic Algorithm for Rule set Production) (Ray et al., 2017), ecological-niche factor analysis (ENFA) (Hirzel et al., 2002), and MaxEnt (maximum entropy) (Phillips et al., 2004; Phillips et al., 2006; Phillips and Dud, 2008; Zaidi et al., 2016).

Mediterranean forest ecosystems cover an area of about 81 million hectares, accounting for 1.5% of the global forest cover (M'Hirit, 1999). They are considered as biodiversity hot spots (Quézel and Médail, 2003; Mendoza-Fernández, 2010) and contain approximately 250 tree species (Quézel, 1999). The study of the circum-Mediterranean vegetation has a major interest in the context of the conservation and preservation of biodiversity (Quézel et al., 1980), as it allows the understanding of the dynamics and evolution of the Mediterranean forest (Quézel, 1999) as well as the assessment of its fragility and its vulnerability to global disturbances and changes (Al Hamndou and Requier-Desjardins, 2008).

The Algerian forests are known for a specific flora that belongs to the Mediterranean forest. Their richness contributes strongly to a climatic, ecological, and socioeconomic balance (Quézel, 1999). The protection and valorization of a forest and near-forest ecosystems has been always at the heart of the political goal of the managers (Saifi, 2015). This can be understood by the succession of action programs whose loopholes have been gradually overcome through the implementation of appropriate improvements (Merdas, 2017).

Despite the efforts made, the forest has been undergoing continuous degradation for several decades, owing to multiple uses and anthropogenic pressure (Madoui, 2002; Quézel and Médail, 2003). Forest dieback is increasingly becoming important due to the long and severe periods of drought (Ahmed et al., 2016).

Holm oak (*Quercus ilex* L.) is a slow-growing, evergreen tolerant species (Rodà, 2000) found primarily in large areas of the Mediterranean regions with cold semiarid to temperate humid bioclimates (Emberger, 1955). It is a forest tree that dominates the transition zones between the temperate forests dominated by hardwoods and the degraded form of forests (Garrigue, maquis, etc) (Terradas, 1999).

The holm oak is one of the primary species covering the Algerian forests that undergoes a strong regression. Several studies have shown a huge decrease over time of the area occupied by this species, which has been estimated to range from 679,000 ha (Boudy, 1955) or 680,000 ha prior to 1985 (Seigue, 1985) to 354,000 ha in 1997 (Ghazi and Lahouati, 1997) and to 108,000 ha in 2007 (DGF, 2007).

This study is based on the modeling of the ecological niche of the species using the maximum entropy method under the present and future climatic conditions associated with a range of variables, namely, climatic factors, factors related to topography, and edaphic and nutritional factors.

The aims of this study were to model the current distribution to determine the areas potentially favorable to the development of holm oak, identify the most contributing environmental factors among the three groups of factors that control the distribution of the holm oak by highlighting its tolerance limits, and finally, assess the impact of future climate change on the spatial distribution of holm oak in eastern Algeria.

MATERIALS AND METHODS

Study Area

The study on the distribution of holm oak was carried out in the eastern Algeria zone. This zone encompasses an enormous ecosystem diversity due to the variety of natural environments resulting from the geomorphological and climatic heterogeneity influenced by its position between the Mediterranean Sea in the north and the Sahara desert in the south, as shown in Figure 1.

In this study, the maximum entropy method was applied to spatial occurrence data of the holm oak, including 39 explanatory variables, to predict the propitious distribution. The performance of the model was statistically evaluated using AUC on the receiver operating characteristic (ROC) curve (Peterson et al., 2008), which allows the assessment of sensitivity (absence of omission errors) and specificity (absence of commission errors) (Fielding and Bell, 1997).

Spatial Occurrence Data of Holm Oak

The spatial occurrence data of the holm oak were collected on field (Figure 2) using a GPS. These data were supplemented from the Tunis–Sfax (Gaussen and Vernet, 1958) vegetation maps taken with their geographical coordinates.

Environmental Variables

The following three groups of environmental variables were used: i) Soil variables comprising the physicochemical and nutritional

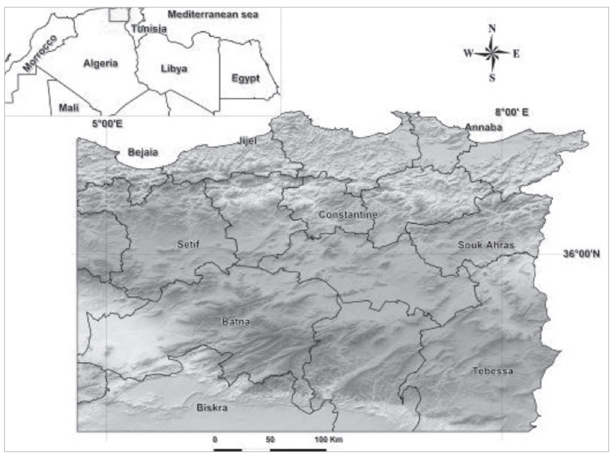

Figure 1. Study area localization

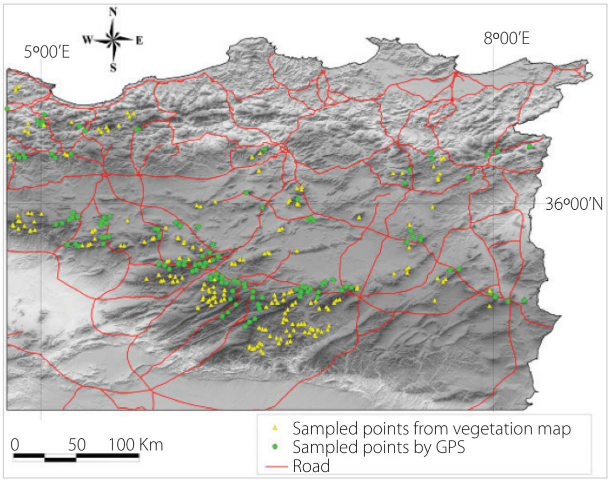

Figure 2. Occurence data of holm oak

characteristics of the soil, namely, clay percentage, silt percentage, sand percentage, organic matter content, soil bulk density, nitrogen content, limestone content, magnesium content, potassium content, sodium content, cation exchange capacity (CEC), and pH. These data were obtained from the Soilgrid database (http://soilgrids.org/: Hengl et al., 2014). The data of the six soil horizons were weighted by horizon thickness to obtain a single layer of data in ASCII Grid format for each soil parameter. ii) Variables related to topography, namely, elevation, the degree of northern orientation (Cos exposure), slope, magnitude of troughs, magnitude of Crete, topographic roughness, and global theoretical monthly radiation. In addition of the distance to the sea (the closest distance between the centroids of the pixels of the kilometric DEM grid and the coastline, these variables are generated from the digital terrain model with a resolution of 30 m (ASTER GDEM) (http://gdem.ersdac.jspacesystems.or.jp) and aggregated to 1-km resolution). iii) Climatic variables were obtained from the BioClim database for the current period (1950–2000). We used the HADGEM2-ES (Hadley Global Environment Model 2 - Earth System) model from the new simulation of climate models carried out under the inter-comparison project phase 5 (CMIP5) of global climate research (www.worldclim.org: Hijmans et al., 2005) for future climatic conditions (2050 and 2070) reflecting the expected climate forcing (IPCC., 2013).

Application of the Model

MaxEnt is a probabilistic and linear probabilistic classifier program based on maximal entropy and estimates the probability of the presence of species based on environmental variables. It requires only the data regarding the presence of species (Phillips et al., 2006).

The principle of the maximum entropy method is to estimate the true occurrence of a species, which is represented as a probability of presence varying between 0 and 1. Thus, when the probability is equal to 1, the presence is estimated as true (Phillips and Dudík, 2008).

The approach used consists of randomly dividing all data into "training" data and "test" data to obtain independent data to evaluate the performance of the model (Fielding and Bell, 1997; Guisan et al., 2003). Thus, a total of 75% of the randomly selected occurrence data was used for modeling (training data), and the remaining 25% (test data) was used for validating the model for 10 replicates of which the selection made is different for each repetition to obtain an average estimation of the model's performance for each repetition (Phillips et al., 2006; Aguirre et al., 2013; Qin et al., 2017).

Performance evaluation is an important step in the validation of the model, which consists of effectuating the omission rate and the predicted area tests to evaluate the predictive performance of the model executed if it is performed as non-random (Phillips et al., 2006).

The analysis of the ROC curve (Fielding and Belle, 1997; Philips et al., 2009) allows the evaluation of the performance of the model through the AUC (area under the curve), which varies between 0 and 1, where 1 represents the maximum performance, and is considered to be weak when the AUC is between 0.5 and 0.7, good when the AUC is between 0.7 and 0.9, and high when the AUC is greater than 0.9 (Swets, 1988; Reddy et al., 2015; Araujo et al., 2015).

RESULTS AND DISCUSSION

Analysis and Evaluation of Model Performance

The curve of the omission rate and the predicted area shows a function of the cumulative threshold, which is calculated on average over the repeated executions of the maximum entropy algorithm. The sensitivity and specificity represent the predicted rate of presence and absence, respectively, as shown in Figure 3. The ROC curve obtained shows a high performance of the model through the calculation of the mean AUC of the test, over the repeated executions of the maximum entropy, which was 0.929 (Kumar, 2014) as shown in Figures 3 and 4.

The AUC provides an independent value that estimates the degree of performance of the model versus that of random expectations (Fielding and Bell, 1997). The following three aspects were taken into account in the evaluation of the model: i) estimation of AUC to evaluate the differences of adjustment of the model, ii) comparison of the maps produced using the occurrence points of the species and the assessment of the spatial agreement of the predictions of presence and absence, and iii) comparison of the contribution of different environmental variables to the model to assess the consistency of selection and contribution of variables (Aguirre-Gutiérrez et al., 2013). The value of the calculated AUC indicates the predictive accuracy of the model, and Figure 4 shows the results of the evaluation confirming the high performance of the model with an AUC value of 0.929 (Lobo et al., 2008; Kumar, 2014; Reddy et al., 2015).

Contribution of Explanatory Variables

Among the 39 variables used, the most contributing explanatory variables to the potentially favorable distribution of *Q. ilex* in eastern Algeria were nitrogen content, elevation, annual mean temperature (bio1), and minimum temperature of the coldest month (bio6). On the other hand, the percentage of sand, the

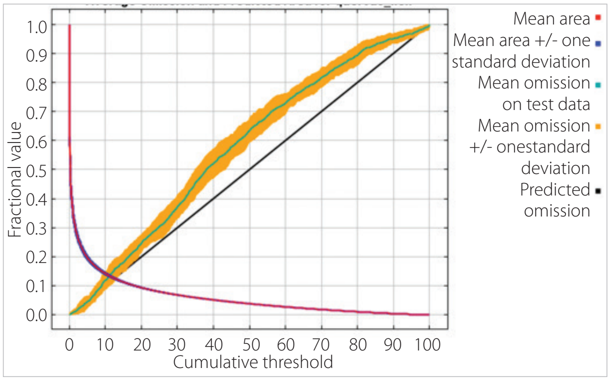

Figure 3. The omission rate of the test and predicted holm oak areas

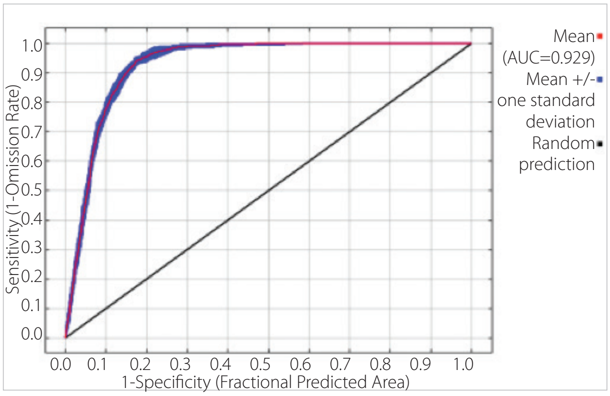

Figure 4. The receiver operating characteristic (ROC) curve

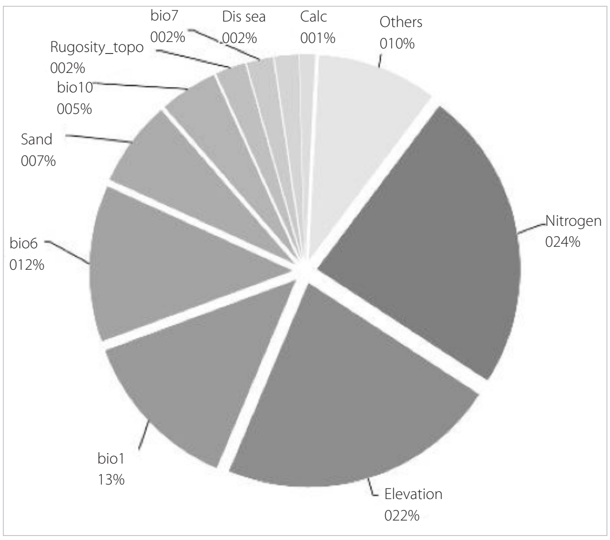

Figure 5. The contribution rate of the most convergent environmental variables for the predicted distribution

warmest quarter average temperature (bio10), topographic roughness (bio7), remoteness from the sea, and limestone content had a lower contribution. The remaining 29 variables had a total contribution of 9.5%, as shown in Figure 5 (Appendix 1).

The variables nitrogen content and elevation exerted a strong positive influence, whereas the annual mean temperature (bio1) and the minimum temperature of the coldest quarter (bio6) strongly and negatively correlated with the distribution of the species. These four variables had the most important contributions to the distribution of holm oak. At this level of perception (kilometric resolution), the climatic variables are the most decisive, with the exception of nitrogen that showed the highest contribution (23.9%).

As shown in Figure 5, *Q. ilex* is present in areas where the nitrogen content is between 1.5 and 3.1 mg/kg and occupies elevations ranging between 950 and 2230 m (Maire, 1926), where the mean annual temperature varies between 7°C and 14°C (Rivas-Martinez., 1980) and the minimum temperature of the coldest quarter varies between −6°C and 0°C (Daget, 1977; Donnadieu, 1977; Quezel, 1979). This affinity to relatively low temperatures reflects a sensitivity to global warming, more specifically to drying of the Mediterranean area, which is due to climate warming, and explains its current distribution and preference for relatively high elevations. Numerous studies have shown that climate change causes the displacement of species ranges toward higher elevations and latitudes (Parmesan and Yohe, 2003; Parry, 2007), thereby leading to new assemblages of species (Williams and Jackson, 2007).

The decrease in nutrient levels in soils, especially nitrogen, is a constraint of tree growth (Leuzinger and Hättenschwiler, 2013). Green oak by adapting and using the most abundant element nitrogen in the soil, there is a balance between the assimilation of CO_2 by the leaves and the absorption of nitrogen by the roots, in an atmosphere rich in CO_2 (Hilbert and Canadell, 1995; Merzouki et al., 1990). The expected increase in CO_2 levels accompanied by water stress affects the assimilation of nitrogen, which results in the strong contribution of this element to the modeling of the distribution of holm oak. The altitudinal shift of green oak stands in the western part of the Mediterranean Basin can be explained by the elevation (Quezel et al., 1980) between 600 and 1200 m in the High Atlas (Barbero and Loisel., 1980), between 400 and 1200 m, and 800 m in the Alpe Maritime (Ozenda., 1966), with similar conclusions being reported for the meso-Mediterranean oak forests of the Grand Atlas (Rivas-Martinez, 1979). The rise in temperature leads to an increase in both the intensity and the duration of periods of water stress, as well as the frequency of droughts (Mouillot et al., 2002). Severe water deficit affects the transport organs of the raw sap, these latter lose their ability to supply water in the conductive tissus, these latter can be filled by air which causes the wasting of the tree (Tyree and Sperry, 1988).

Holm Oak Presence Probability Maps

The propitious habitat predicted for the period 1950–2000 is spread along the Saharan Atlas, the Hodna Mountains, the Aurès Mountains, the Nememmcha Mountains, and the Tebessa Mountains. Within the Tellian Atlas, the holm oak is expected to be present in the Babor Mountains and the Constantine Mountains, as shown in Figure 6.

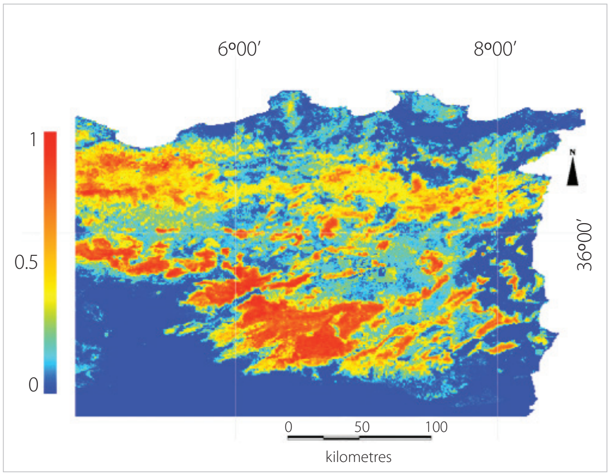

Figure 6. Holm oak distribution probabilities in eastern Algeria for the period 1950–2000

Table 1. Spatiotemporal evolution of the modeled favorable area and its altitudinal distribution

		Area (ha)	Decreased area	Rate of decrease in %	Elevation range (m)
The current period		183000	-	-	950–2230
	RPC26	98000	85 000	46.45	1180–2230
2050	RPC45	75000	108000	59.01	1250–2230
	RPC60	63000	120000	65.57	1300–2230
	RPC85	58000	125000	68.30	1430–2230
	RPC26	44000	139000	75.95	1500–2230
2070	RPC45	41000	142000	77.59	1550–2230
	RPC60	38000	145000	79.76	1600–2230
	RPC85	36000	147000	80.32	1650–2230

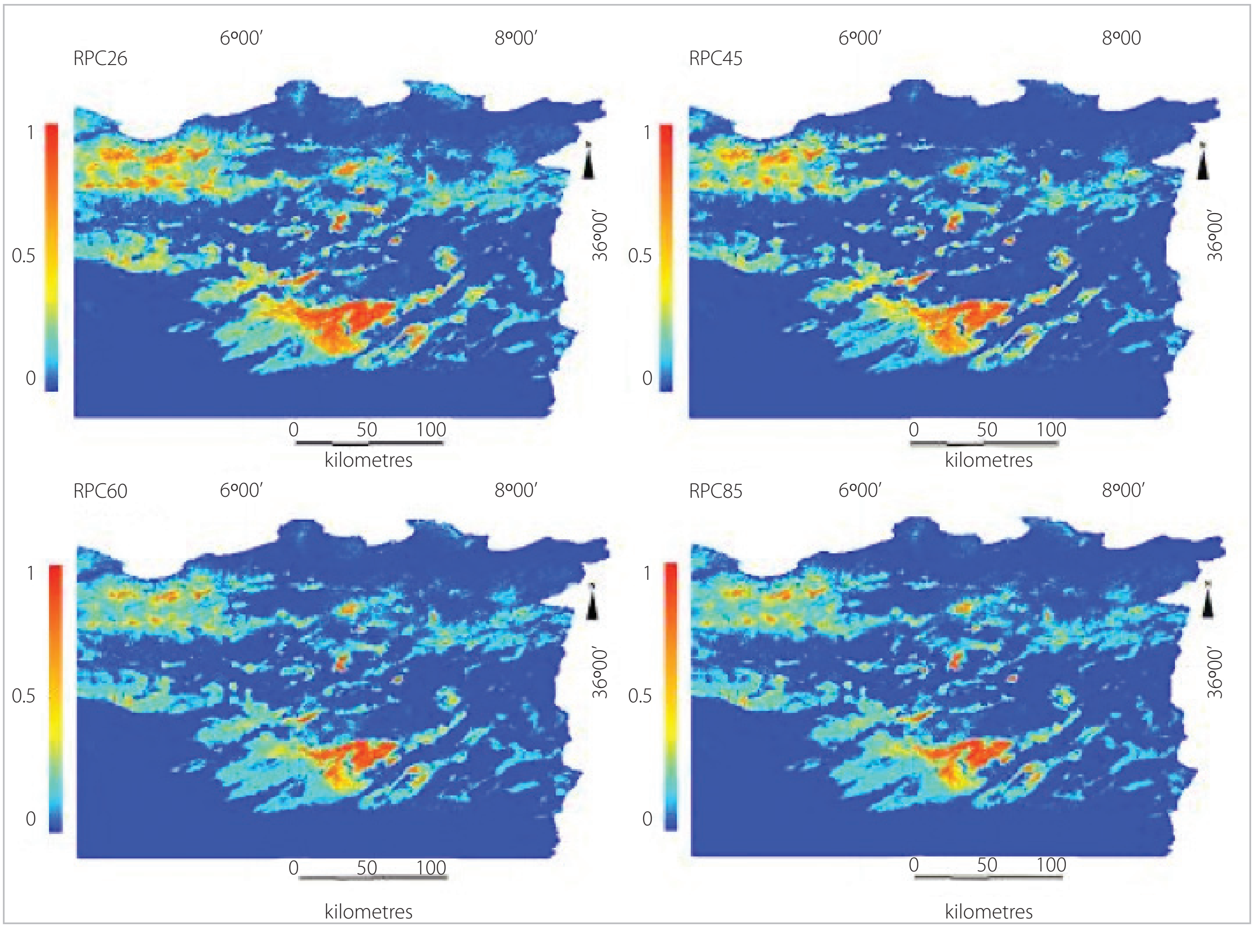

Figure 7. Probability of the presence of holm oak for the four scenarios of the 2050 horizon

The results of the prediction of distribution and the variables defining the potential ecological niches of the holm oak generally appear to be in agreement with the current knowledge of the ecological requirements of the species (Maire, 1926; Daget, 1977; Donnadieu., 1977; Quezel, 1979; Rivas-Martinez, 1980). The modeling approach has correctly predicted a suitable habitat for the holm oak in a fragmented area occupying primarily the Aurès Mountains and the high elevations of the Tellian Atlas. The predicted favorable area of the holm oak for the period 1950–2000 was estimated at 183,000 ha.

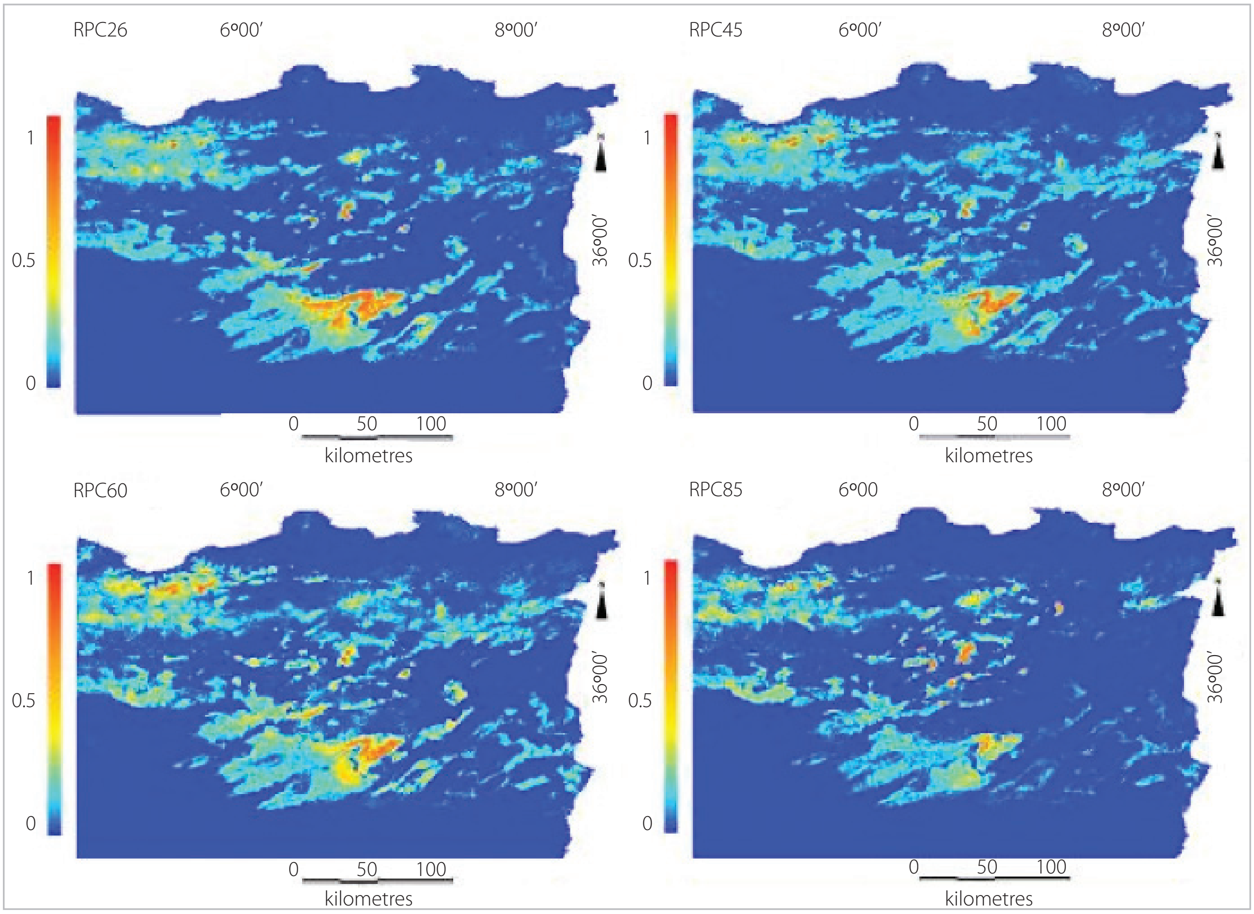

Figure 8. Probability of the presence of holm oak for the four scenarios of the 2070 horizon

The results have also allowed us to estimate the potential areas obtained under future climate projections by 2050 and 2070, as shown in Figures 7 and 8, as well as the corresponding elevation ranges. These findings highlight that the area favorable to the development of the holm oak will be strongly shrunk with retreat to high elevations, as shown in Table 1.

According to Pouteau et al. (2010), upward displacements of the vegetation levels, with respect to the present levels, of 220 m in 2050 (with a temperature rise of +1.4°C) and of 490 m in 2100 (with a temperature rise of +3.1°C) are projected under the A1B emission scenario. Consequently, the tropical subalpine zone will disappear completely before 2100. These findings are in concordance with our results describing the vertical displacements of the projected lower boundary, which are estimated at 1180, 1250, 1300, and 1430 m by 2050 and at 1500, 1550, 1600, and 1650 m by 2070 for the RPC26, RPC45, RPC65, and RPC85 scenarios, respectively, as shown in Table 1.

Laala and Allatou (2016) estimated a degradation rate of 17% for the forest massifs in eastern Algeria, of which 2.19% includes the degradation rate of holm oak for the period 2002–2011. This result describes the consequences of current climatic disturbances over a 10-year period, which supports the predictions obtained in this research for the most pessimistic future climate projections by 2050 and 2070. Furthermore, the spatial distributions of areas suitable to the development of holm oak will be sharply reduced for all scenarios (RPCs). These suitable areas are indeed estimated to decrease at the rates of 53.55%, 59.01%, 65.57%, and 68.30% of the current areas by 2050 and at 75.95%, 77.59%, 79.76%, and 80.32% by 2070 for the RPC26, RPC45, RPC60, and RPC85 scenarios, respectively (Figures 7 and 8).

In particular, the elevations of the Saharan Atlas would constitute the potential refuge for holm oak, whereas the low and moderate elevations will become less favorable.

CONCLUSION

This study has allowed us to better understand the distribution and ecology of *Q. ilex* to successfully identify its current potential habitats and to project into its future potential ecological niche. The future simulations showed a strong response of the species to climate change, with a more pronounced shrinkage by 2070, corresponding to a decrease of 80.32% of the current area for the worst-case scenario (RPC85). Such an alarming result requires a serious and relevant policy response through the establishment of effective and sustainable strategies. However, other factors that influence the distribution of forest species, such as biotic interactions and seed dispersal capabilities, must also be taken into account, including the adaptive capacities. In this study, the shrinkage results of green oak were overestimated because the method does not take into account atmospheric CO_2 levels and their effects on stomatal regulation in response to water stress, thereby limiting, on the one hand, the assimilation of CO_2 by the species and, on the other hand, the decrease in evapotranspiration caused by the increase in temperature. The high spatial resolution of the variables would allow obtaining a better understanding of the spatial distribution of the holm oak at a fine scale to draw appropriate conclusions for better conservation and decision-making.

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Appendix 1. Table showing the contribution of explanatory variables

Variable	Abbreviation	Percent contribution
Nitrogen (mg/kg)	Nitrogen	23.9
Elevation (m)	Elevation	22.2
Annual Mean Temperature (°C)	bio1	13
Minimum Temperature of Coldest Month (°C)	bio6	12.4
Sand (%)	Sand	6.8
Mean Temperature of Warmest Quarter (°C)	bio10	4.6
Rugosity Topographic	RUG	2.4
Annual Temperature Range (BIO5-BIO6)	bio7	2.1
Distance to sea (m)	Dis_mer	1.9
Total limestone (mg/kg)	Calc	1.2
Precipitation of Coldest Quarter (mm)	bio19	0.9
Maximum Temperature of Warmest Month (°C)	bio5	0.8
Precipitation Seasonality (Coefficient of Variation)	bio15	0.8
Silt (%)	Silt	0.6
Potassium (cmolc/kg)	Potass	0.5
Bulk density (kg/m^3)	Balckdens	0.5
Mean Temperature of Wettest Quarter (°C)	bio8	0.4
Organic Matter (g/kg)	Mo	0.4
Precipitation of Driest Month (mm)	bio14	0.3
Cation exchange capacity of soil (cmolc/kg)	CEC	0.3
Sodium (cmolc/kg)	Sodium	0.3
Precipitation of Warmest Quarter (mm)	bio18	0.3
Precipitation of Driest Quarter (mm)	bio17	0.3
Magnesium (cmolc/kg)	Magn	0.3
Degree of north orientation	Cos_exposition	0.2
Temperature Seasonality (standard deviation *100)	bio4	0.2
Precipitation of Wettest Quarter (mm)	bio16	0.2
Clay (%)	Clay	0.2
Isothermality (BIO2/BIO7) (*100)	bio3	0.2
Mean Temperature of Driest Quarter (°C)	bio9	0.2
Mean Temperature of Coldest Quarter (°C)	bio11	0.2
Theoretical global radiation (March) w/m^2	ReG_Fev	0.2
Annual Precipitation (mm)	bio12	0.2
Theoretical global radiation (March) w/m^2	ReG_Dec	0.1
	ReG_Aout	0.1
Mean Diurnal Range (Mean of monthly) (°C)	bio2	0.1
	ReG_Mai	0.1
Precipitation of Wettest Month (mm)	bio13	0.1
pH	pH	0.1
Magnitude Crete (m)	Magnitude crete	0.1
Slope (%)	slope	0.1
Global radiation (November) w/m^2	ReG_Nov	0.1
Theoretical global radiation (September) w/m^2	ReG_Sept	0
Theoretical global radiation (July) w/m^2	ReG_Juillet	0
Theoretical global radiation (March) w/m^2	ReG_Mars	0
Theoretical global radiation (June) w/m^2	ReG_Juin	0
Theoretical global radiation (year) w/m^2		
Theoretical global radiation (April) w/m^2	ReG_Avr	0
Theoretical global radiation (October) w/m^2	ReG_Oct	0
Theoretical global radiation (January) w/m^2	ReG_Jan	0

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Original Article

Correlation between the phenology of leafing and growth characteristics of Douglas-fir provenances in Serbia

Sırbistan'da Douglas göknarının gelişim özellikleri ile yapraklanma fenolojisi arasındaki korelasyon

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ABSTRACT

The study of periodic plant life cycle events, or phenology, is of great importance both in the process of species introduction and in the period of its adaptation to new environmental conditions. We assumed that the leaf-out process correlates with the elements of plant growth. The research we focused on these dependencies in order to select the provenances which would be the most suitable for introduction in Serbia. The research was aimed at investigate the dependencies of leafing on the height, diameter, and height increment of Douglas-fir provenances within the experiment in Serbia. The experiment was established using native seed material originating from different provenances from a part of the natural range of Douglas-fir distribution in North America. Therefore, it has a significant effect on the elements of plant growth. The obtained data were analyzed using descriptive statistics, analysis of variance, regression and correlation. It was concluded that the correlation between the time of leaf-out (bud break) and morphological characters of Douglas-fir trees of different provenances was statistically weak. The correlation was the strongest between the time of leaf-out and the height of plants.

Keywords: *Pseudotsuga menziesii*, introduction, leaf-out, height, height increment

ÖZ

Periyodik bitki hayat döngüsü olaylarını inceleyen fenoloji, türlerin başlangıç süreci ve de yeni çevre koşullarına adaptasyon sürecinde önemlidir. Yapraklanma sürecinin bitkinin büyüme unsurlarıyla ilişkili olduğunu düşündük. Bu çalışmada, Sırbistan'da Douglas göknar ağacının yetiştirilmesi için en uygun olan kaynakları seçmek amacıyla bu faktörlere odaklandık. Yapraklanmanın yükseklik, çap ve yükseklik artışına olan bağımlılığının incelenmesi amaçlandı. Deney Kuzey Amerika'da doğal Douglas göknarı dağılımı gösteren bölgeden farklı kaynaklardan alınan doğal tohum materyali kullanılarak yapıldı. Bu nedenle, bitkinin gelişimi unsurları üzerinde anlamlı etkiler gözlendi. Elde edilen veriler tanımlayıcı istatikler, varyans analizi, regresyon ve korelasyon kullanılarak değerlendirildi. Yapraklanma (tomurcukların patlaması) zamanı ile farklı kaynaklardan alınan Douglas göknarının morfolojik özellikleri arasındaki korelasyon istatiksel olarak zayıftı. Diğer yandan, yapraklanma zamanı ile bitkilerin yükseklikleri arasında daha güçlü bir ilişki izlendi.

Anahtar Kelimeler: *Pseudotsuga menziesii*, başlangıç, yapraklanma, yükseklik, yükseklik artışı

INTRODUCTION

Phenology studies the timing of bud dormancy breaking and leafing or opening of dormant winter buds. It has emerged from the shadows to become a major component of climate change studies. In part this is because the phenological responses of species to temperature, particularly in plants, are very strong. Leafing-out of woody plants marks the beginning of a growing season in forests and it is one of the most important drivers of ecosystem processes. There is substantial variation in the timing of leaf-out, both within and among species, but the leaf development of almost all tree and shrub species is highly sensitive to temperature (Polgar and Primack, 2011).

Carolus Linnaeus is looked upon as the father of modern phenological networks. The first known phenological network was installed by him in Sweden in the middle of the 18th century. In his work `*Philosophia Botanica*`, he outlined methods for compiling annual plant calendars of leaf opening, flowering, fruiting and leaf fall,

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together with climatological observations "... so as to show how areas differ..." (Linnaeus, 1751).

Phenological change is relatively easy to identify, especially in comparison with changes in distribution, fecundity, population size, morphology, etc. Even with the relatively modest levels of global warming experienced so far, phenological change has become very evident (Sparks et al., 2009a; Sparks et al., 2009b).

Genetic regulation of the leaf-out process has been well-documented (Campbell and Sugano, 1975; White et al., 1979; Li and Adams, 1993;Myking and Heide, 1995). Furthermore, many authors (Campbell and Sugano, 1979 ; White et al., 1979; Li and Adams, 1993; Myking and Heide, 1995; Partanen et al., 1998; Vesk and Westoby, 2004; Ziello, et al. 2009; Caroline and Primack, 2011) have investigated phenological p*rocesses* by which *bud burst* is *synchronized* to *seasonal cycles*.

Phenological recording of plants in Europe has a long history and is currently concentrated in the hands of state meteorological agencies and focused on species of commercial importance (agricultural and horticultural crops, forest trees) or amenity species associated with human settlements (Nekovar et al., 2008).

Conifer growth is driven by genetic potential, physiological and morphological responses to environmental conditions (Harrington and Chain, 1994), which gives special importance to phenological studies of introduced species.

Douglas-fir (*Pseudotsuga menziesii*, Mirb/Franco) is a conifer species of high commercial importance in Canada and North America (Arno et al.,1977). In Europe, it has been recognized as a productive fast-growing species with a high degree of adaptability. Adapted to a moist, mild climate, it grows bigger and more rapidly than the in land variety. These trees commonly live more than 500 years and occasionally more than1,000 years (Franklin et al., 1981; Hermann et al.,1990).

Provenance test is the best way to test seed transfer, genetic identity and potential growth of Douglas-fir trees. Otherwise, introduction may be risky and time-consuming, the choice of provenance wrong and its adaptation inadequate. The model of provenance test stresses the significance of genetic differences and reveals significant differences and dependencies that provenances show in the given period of phenological research. Provenance tests are often used to determine genetic responses of seed sources to transfer to different climates (Schmidtling 1994).

The phenology of bud burst is fundamental to tree survival and growth in temperate and boreal regions of the world (Sakai and Larcher, 1987; Bailey and Harrington, 2006). Plants have evolved mechanisms to use photoperiod and temperature cues to balance the benefits from early bud burst with the probability of significant damage from spring frost (Sakai and Larcher, 1987; Hannerz, 1999).

Early expansion of vegetative tissue is advantageous for producing biomass and maintaining site dominance; however, early tissue expansion also increases the risk of frost damage from late-spring freezing temperatures (Heide, 2003). In species with preformed growth, buds are the plant investment for the crown growth in the next year (Heide, 2003).

The task of plant phenology is to observe and record the periodically recurring growth stages and to study the regularities and dependency of the yearly cycles of development on environmental conditions (Koch and Scheifinger, 2004; Koch et al., 2009).

Since provenance test is the best way to test seed transfer, genetic identity and potential growth of Douglas-fir trees, the Institute of Forestry in Belgrade established the first tests of Douglas-fir in Serbia with native seed material originating from Canada and North America (Lavadinović and Koprivica, 1996; Lavadinović and Koprivica, 1999; Lavadinović et al., 2001).

MATERIALS AND METHODS

Seed Material

The collection of native Douglas-fir seeds, which was obtained from the part of the natural range of Douglas-fir in North America (Table 1), was used to produce seedlings. Having been given the appropriate treatment, 2+2 transplants were fit to be planted on the mountain of Juhor (central Serbia).

Table 1. Geographical features of Douglas-fir provenances in Juhor experiment

	Provenance Code	Code number	Latitude (°)	Longitude (°)	Altitude (m)
Oregon	205-15	1	43.7	123.0	750
Oregon	205-14	2	43.8	122.5	1200
Oregon	202-27	3	45.0	122.4	450
Oregon	205-37	4	45.0	121.0	600
Washington	204-07	9	49.0	119.0	1200
Oregon	205-13	10	43.8	122.5	1050
Oregon	205-18	11	44.2	122.2	600
Oregon	202-22	12	42.5	122.5	1200
Washington	202-17	15	47.6	121.7	600
Oregon	201-10	16	44.5	119.0	1350
Washington	201-06	17	49.0	120.0	750
Oregon	202-19	18	45.3	123.8	300
Oregon	205-11	20	45.0	123.0	150
New Mexico	202-04	22	32.9	105.7	2682
New Mexico	202-10	23	36.0	106.0	2667
Oregon	202-31	24	44.3	118.8	1500
Oregon	205-29	26	42.6	122.8	900
Oregon	205-08	27	42.7	122.5	1050
Oregon	204-04	30	45.0	121.5	900
Washington	205-17	31	47.7	123.0	300

The average latitude of Douglas-fir provenances in the sample is 44.0 degrees, the longitude is 120 degrees and the altitude amounts to 1010 m above sea level. The coefficients of variation are 8.7%, 4.2% and 67.1% respectively.

Juhor Provenance Test

Douglas-fir provenance test on the mountain of Juhor (43º47'N, 18º58'E and 650 m. a.s.l.) was established on the site of mountain beech forest (*Fagetum moesiaca montanum* Jovanović 1976). It was set in a random block system. The test included 20 provenances with 15 repetitions (blocks). The blocks were arranged in the direction of contour lines. The plants were spaced 2 x 2 m. The same spacing was between the provenances and the blocks were spaced 4 m apart. Each block included twelve plants of each provenance, which means that each block had 240 plants, and the whole test 3600 plants, covering an area of about 2 ha. Parent rock contains only shales and soil is brown forest soil. This area is under the influence of humid continental climate, which is characterized by warm and dry summers, with the temperature ranging from 20 to 35°C and harsh and cold winters with the temperatures between 0 to -15°C, with sharp frosts and a deep snow cover. This area is typically characterized by uneven distributions of rainfall during the year.

Method of Data Collecting and Processing

Field research included measurements of tree dendrometric characters (height, diameter at breast height and height increment) and recording of *bud flushing phenology* in different provenances (number of days from the beginning of the calendar year to the date of leaf-out). A caliper was used to measure tree diameters at 1.3 meters above ground, with an accuracy of 1 mm. The height and height increment were measured using a tree measuring stick, with an accuracy of 1 cm. Phenological characteristics (changes in the development of buds) were recorded twice a week and the observed changes were recorded in the Manual for the collection of field data. The results of the measurements of the morphological characters of Douglas-fir trees and monitoring of phenological characteristics are shown in Table 2.

Several statistical methods were used for the purpose of processing data on leaf-out phenology and the elements of tree growth in different Douglas-fir provenances. They are: descriptive statistics, analysis of variance, regression and correlation.

The correlation between the timing of leaf-out and morphological characters (height, diameter and height increment) of the trees belonging to the studied Douglas-fir provenances were studied using the methods of simple and multiple regression and correlation.

RESULTS AND DISCUSSION

Descriptive Statistics of the Observed Provenance Characteristics

Table 3 presents the most important statistical indicators of leaf-out timing (Y) and height (X1), diameter (X_2) and height increment (X_3) of Douglas- fir provenances.

Table 2. Leaf-out timing and morphological characters of Douglas-fir trees in Juhor provenance test

Provenance number	Leaf-out (day)	Bud break (date)	Height (m)	Diameter (cm)	Height Increment (cm)
1	145.6	25.05.	5.16	11.5	89
2	143.3	23.05.	5.17	11.3	76
3	146.8	26.05.	5.58	12.0	88
4	146.5	26.05.	4.99	10.8	84
9	146.6	26.05.	2.82	6.5	43
10	147.7	27.05.	5.06	10.9	83
11	142.8	22.05.	5.24	11.8	85
12	144.8	24.05.	4.72	11.0	80
15	149.2	29.05.	5.16	11.3	83
16	148.7	28.05.	3.53	8.2	56
17	136.6	16.05.	3.48	8.2	57
18	147.0	27.05.	5.37	11.6	84
20	150.0	30.05.	5.10	11.6	86
22	141.9	21.05.	3.94	9.0	64
23	139.7	19.05.	3.70	8.1	62
24	147.0	27.05.	2.86	6.7	45
26	143.3	23.05.	4.86	11.2	82
27	144.6	24.05.	4.63	10.4	78
30	147.3	27.05.	4.69	10.3	77
31	155.1	04.06.	5.29	10.6	77

Table 3. Basic statistical indicators of the observed variables

	Variables			
Statistical indices	Y_1	X_1	X_2	X_3
Count	20	20	20	20
Average	145.72	4.56	10.15	73.95
Standard deviation	3.95	0.85	1.72	14.22
Coeff. of variation (%)	2.71	18.74	16.95	19.24
Minimum	136.6	2.82	6.50	43.0
Maximum	155.1	5.58	12.0	89.0
Range	18.5	2.76	5.5	46.0
Standard skewness	-0.18	-1.77	-1.88	-1.99
Standard kurtosis	1.37	-0.33	-0.19	-0.01

In the following analyses the time of bud break is taken as the dependent variable and the independent variables are: height, diameter, and height increment.

Table 4. The coefficients of linear correlation of the observed variables

Variables	Y	X_1	X_2	X_3
Y	-	0.3280	0.2342	0.2329
		(20)	(20)	(20)
		0.1580	0.3202	0.3231
X1		-	0.9808	0.9669
			(20)	(20)
			0.0000	0.0000
X2			-	0.9802
				(20)
				0.0000
X3				-

Table 5a. The parabolic regression model

Parameter	Estimate	Error	Statistic	p
Constant	181.721	24.8326	7.31784	0.0000
X_1	-19.9618	12.2606	-1.62812	0.1219
X_1^2	2.55959	1.45678	1.75702	0.0969

Table 5b. Analysis of variance for regression

Source	Sum of Squares	Df	Mean Square	F-Ratio	p
Model	72.4194	2	36.2097	2.75	0.0920
Residual	223.478	17	13.1458		
Total	295.897	19			

Regression equation is $Y=181.721–19.9618\ X_1+2.55959\ X_1^2$.
Coefficient of determination is 24.47%.
Standard error of regression is 3.63 days.

Table 6a. The parabolic regression model

Parameter	Estimate	Error	Statistic t	p
Constant	164.44	33.4568	4.915	0.0001
X_2	-4.8425	7.36632	-0.657384	0.5197
X_2^2	0.287578	0.39275	0.732218	0.4740

Table 6b. Analysis of variance for regression

Source	Sum of Squares	Df	Mean Square	F-Ratio	p
Model	24.7854	2	12.3927	0.78	0.4754
Residual	271.112	17	15.9478		
Total	295.897	19			

Regression equation is $Y=164.44–4.8425\ X_2+0.287578\ X_2^2$
Coefficient of determination is 8.37%.
Standard error of regression is 3.99 days.

Table 7a. The parabolic regression model

Parameter	Estimate	Error	Statistic t	p
Constant	169.3	23.4379	7.22331	0.0000
X_3	-0.829983	0.727106	-1.14149	0.2695
X_3^2	0.0066779	0.00540745	1.23494	0.2336

Table 7b. Analysis of variance for regression

Source	Sum of Squares	Df	Mean Square	F-Ratio	p
Model	39.0895	2	19.5447	1.29	0.2999
Residual	256.808	17	15.1064		
Total	295.897	19			

Regression equation is $Y=169.3–0.829983\ X_3+0.0066779\ X_3^2$
Coefficient of determination is 13.21%.
Standard error of regression is 3.88 days.

The Correlation between the Observed Characteristics of Provenances

Table 4 gives the coefficients of simple linear correlation (with the sample size and statistical significance) between the observed characteristics of Douglas-fir provenances.

We are most interested in the coefficient of correlation between the budbreak timing (the number of days from the beginning of the year) and the tree height, diameter, and height increment.

Regression between the Observed Provenance Characteristics

Linear and parabolic dependence of the bud break (leaf-out) on the morphological characters of different provenances of Douglas fir trees was preliminary tested. Based on the obtained values of statistical indicators of regression and correlation, it was concluded that in all cases the curvilinear relationship was slightly better than the linear one. Therefore, we present only the results of parabolic regression and correlation.

Dependence of the Leaf-Out Timing (Y) on the Provenance Height (X_1)

Tables 5a and 5b present statistical characteristics of the observed parabolic regression model.

Dependence of the Leaf-Out Timing (Y) on the Provenance Diameter (X_2)

Tables 6a and 6b present statistical characteristics of the observed parabolic regression model.

Dependence of the Leaf-Out Timing (Y) on the Provenance Height Increment (X_3)

Tables 7a and 7b present statistical characteristics of the observed parabolic regression model.

Dependence of the Leaf-Out Timing (Y) on the Provenance Height (X_1), Diameter (X_2) and Height Increment (X_3)

Tables 8a and 8b present statistical indicators of the multiple curvilinear regression model.

Table 8a. Multiple curvilinear regression model

Parameter	Estimate	Error	Statistic t	p
Constant	110.374	36.8723	2.99341	0.0104
X_1	105.136	73.8815	1.42304	0.1783
X_1^2	-9.17071	7.43524	-1.23341	0.2393
X_2	13.4992	26.6501	0.506533	0.6210
X_2^2	-0.922698	1.25712	-0.733977	0.4760
X_3	-7.46076	2.87993	-2.59061	0.0224
X_3^2	0.0468486	0.0177518	2.63909	0.0204

Table 8b. Analysis of variance for multiple curvilinear regression

Source	Sum of Squares	Df	Mean Square	F-Ratio	p
Model	174.251	6	29.0419	3.10	0.0411
Residual	121.646	13	9.35739		
Total	295.897	19			

Regression equation is $Y=110.374+105.136\ X_1-9.17071\ X_1^2+13.4992\ X_2-0.922698\ X_2^2-7.46076\ X_3+0.0468486\ X_3^2$
Coefficient of determination is 58.89%.
Standard error of regression is 3.05 days.

Table 8b shows that the observed multiple regression is statistically significant ($p<0.05$) on the whole. However, the impact of many variables in Table 8a is not statistically significant ($p> 0.05$). If we apply the stepwise regression, only the constant remains in the model.

Table 3 shows that the coefficient variation in the number of days (from the beginning of the year) to the bud break is very small (2.71%), which means that the studied Douglas-fir provenances do not differ much in this respect. The minimum number of days is 137 and the maximum 155. It means that all provenances open their buds within 18 days. Regarding height, diameter and height increment the provenances vary in a narrow range of 17% for diameters to 19% for height and height increment. The obtained results suggest that the correlation between the budbreak timing and the height, diameter, and height increment is small, which was later confirmed in the analysis performed by means of regression and correlation.

Table 4 shows that the none of the coefficients of correlation are statistically significant ($p<0.05$). The highest correlation coefficient is between the number of days to the bud break and height (0.328) followed by diameter (0.234) and height increment (0.233). In all cases, the relationship is linear and positive, which means that an increase in the height, diameter or height increment of Douglas-fir provenances prolong the budbreak timing (increases the number of days). Regression and correlation will provide a better insight into these results. The relationship between the elements of growth (height, diameter, and height increment) is naturally statistically significant ($p<0.05$).

Provenance height accounts for approximately 24.4% of the total provenance variance in the number of days to the leaf-out. The rest is due to some other factors that haven`t been considered by this research. Standard error of regression is 3.63 days.

Provenance diameter accounts for only 8.37% of the total provenance variance in the number of days to the leaf-out. Standard error of regression is 3.99 days.

Provenance height increment accounts for only 13.21% of the total provenance variance in the number of days to the leaf-out. Standard error of regression is 3.88 days.

It follows that the combined changes in the height, diameter, and height increment of provenances account for 58.89% of changes in the leaf-out timing of Douglas-fir provenances in the Juhor test. The standard error of regression is 3.05 days.

CONCLUSION

The research of different Douglas-fir provenances originating from North America was aimed at determining the dependences of plant leaf-out timing on the elements of growth. The following conclusions are:

Provenances don`t differ much in the date of leaf-out onset. The coefficient of variation is 2.71%. However, all the provenances that were included in the Juhor experiment leafed out within 18 days. This number of days can bring a lot of risks to plants, since spring is a season with sharp fluctuations in air temperatures. The plants of provenance 31 were the last to leaf out (on the 155th day from the beginning of the year), while the plants of provenance 17 had the earliest leaf -out onset (on the 137th day from the beginning of the year).

Since the provenances vary in height, diameter and height increment in a narrow range of 17% for diameter up to 19% for height and height increment, the dependence of the budbreak timing on height, diameter, and height increment is in the simple regression models small and statistically insignificant. However, the relationship obtained in the fixed model of a multiple curvilinear regression is statistically significant ($p<0.05$). The combined variation in the height, diameter, and height increment of provenances accounts for 58.89% of the variation in the leaf-out timing (bud break).

In all cases, there is a simple positive linear correlation, which means that with an increase in the height, diameter and height increment of Douglas-fir provenances, they increase the number of days to the bud break. More successful provenance (measured by the dimensions and height increments of their trees) broke buds later than the less successful ones. However, the parabolic relationship presented in this paper showed a bit more reliable values of statistical indicators.

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Original Article

Use of ecological value analysis for prioritizing areas for nature conservation and restoration

Doğa koruma ve restorasyon öncelikli alanların belirlenmesinde ekolojik değer analizinin kullanımı

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ABSTRACT

Many studies made in recent years revealed the fact that nature conservation and restoration practises have been required in our forests, whose natural structure has been degraded or destroyed by anthropogenic interference, containing a high level of biodiversity and situated in three different phyto-geographical regions. Considering the recent developments on these subjects mainly in Europe and North America, it is necessary to carry on nature conservation and restoration studies by applying different planning methodology for various landscape types. It was aimed with this study to develop a new planning concept for determining nature conservation and restoration priority areas based on the basic principles of "ecological value analysis", which is widely used today in many developed countries. Yedigöller National Park (Bolu) was selected as study area. Ecological value analysis was performed with the assessment of data collected from 80 sample plots related to 16 parameters, which are the rarity of plant communities and their spatial distribution, hemeroby degrees, diversity and rarity of plant taxa, endemic plant taxa, some components of forest structure (layerness, stand age, mixture type, mixture rate, canopy closure) and deadwood amount by using relation matrices and direct scoring. The results revealed that; (1) there is a rather variable landscape structure depending on naturalness, diversity of habitats, species diversity, rarity and endemism, (2) 90% of the study area has "medium" ecological value, (3) detailed ecological value scale scores ranges between 15-30, (4) anthropogenic disturbance is mainly determined in the area close to the lakes, (5) use of many parameters as possible considering the landscape structure improved the sensitivity of the analysis as well as providing the sophisticated analysis of the study area.

Keywords: Landscape planning, nature conservation, restoration, ecological value, land use

ÖZ

Son yıllarda yapılan birçok çalışma, üç fitocoğrafik rejyonda bulunup yüksek derecede biyolojik çeşitlilğe ev sahipliği yapan ancak doğal yapısı antropojenik müdahalelerle bozulmuş veya tahrip olmuş orman peyzajlarında doğa koruma ve restorasyon çalışmalarına gerek duyulduğunu ortaya koymuştur. Özellikle Avrupa ve Kuzey Amerika'da son yıllarda bu konulardaki son gelişmeler göz önünde bulundurulduğunda, çeşitli peyzaj tipleri için farklı planlama yöntemlerinin uygulandığı doğa koruma ve restorasyon çalışmalarının yapılmasının önemli olduğu görülmektedir. Bu çalışmada, doğa koruma ve restorasyon öncelikli alanların belirlenmesine yönelik olarak günümüzde birçok gelişmiş ülkede yaygın olarak kullanılan "ekolojik değer analizi"nin temel prensiplerine dayanan bir planlama konsepti geliştirilmesi amaçlanmıştır. Çalışma alanı olarak Yedigöller Milli Parkı (Bolu) seçilmiştir. Ekolojik değer analizi 80 örnek alandan toplanan bitki toplumlarının enderliği ve bunların mekansal dağılımı, hemerobi dereceleri, bitki taksonlarının çeşitliliği ve enderliği, endemik bitki taksonları, orman strüktürünün bazı bileşenleri (katlılık, meşcere yaşı, karışım biçimi, karışım oranı, meşcere kapalılığı) ve ölü ağaç miktarına ilişkin 16 parametrenin değerlendirilmesiyle ilişki matrisleri ve doğrudan puanlama kullanılarak gerçekleştirilmiştir. Elde edilen sonuçlara göre; (1) doğallık, yaşam alanı çeşitliliği, tür çeşitliliği, enderlik ve endemikliğe bağlı olarak oldukça değişken bir peyzaj yapısı vardır, (2) araştırma alanının %90'ı "orta" ekolojişk değere sahiptir, (3) ayrıntılı ekolojik değer skalası puanları 15-30 arasında değişmektedir, (4) antropojenik etki büyük oranda göllere yakın olan alanda belirlenmiştir, (5) peyzaj yapısına bağlı olarak mümkün olduğunca fazla parametrenin kullanılması alanın çok yönlü olarak analiz edilmesini sağladığı gibi analizin hassasiyetini de arttırmıştır.

Anahtar Kelimeler: Peyzaj planlama, doğa koruma, restorasyon, ekolojik değer, arazi kullanımı

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INTRODUCTION

The overuse of natural resources degrades natural habitats, while it may cause the fragmentation and even loss of living areas (Andren, 1994; Harrison and Brauna, 1999; Fahrig, 2003). These alterations have a direct effect on landscape structure (Robinson et al., 1992; Haila, 2002; Lindenmayer et al., 2003) and may manifest themselves with various changes in plant and animal communities (Watt, 1947; Symstad et al., 1998; Villard et al., 1999). Forests are accepted as one of the important natural habitats subject to nature conservation and restoration owing to the rich biodiversity they contain (Enoksson et al., 1995; Scherzinger, 1996; Carr, 1999; Lindenmayer et al., 2006).

Turkey has been known as a country containing diverse natural and cultural landscapes scattered into three phytogeographical regions (Davis, 1979), while 26% of the country is covered with forests. Although these forests have been continuously affected by anthropogenic uses through history (Thirgood, 1987; Perlin, 1989; Kehl, 1995; Rackham and Moody, 1996), they still remain reasonably intact and various vegetation types represent differences in floristic diversity including climate, geology, topography, soil structure and endemism (Çolak et al. 2010). Currently, about 8.10% of the country's land surface is designated as protected areas (Anonymous, 2002-2013) (40 national parks, 31 nature conservation areas, 203 nature parks, 112 nature monuments, 81 wildlife conservation areas, 16 special environmental protection areas, 14 Ramsar sites and 1 biosphere reserve), which mainly focus on forests, wetlands and mountain habitats (DKMPGM, 2015). However, there are serious concerns about the planning and management of protected areas globally, that they turn into "paper parks" in a while (Mulongoy and Chape, 2004). Research show that only 25% of protected forest landscapes are planned and managed properly and only 1% are safe in the long term (Secreteriat of the Convention on Biological Diversity, 2004). Main threats on the protected areas are determined as direct anthropogenic effects (e.g. habitat fragmentation, urbanization, development of infrastructure, mining, recreational activities, over-grazing, hunting, etc.), socio-political and economic factors (e.g. lack of political support, insufficient financial resources and employees, lacking or ineffective nature conservation policies, negative approach of local people, etc.) and flaws and deficiencies of management (lack of strategic plans, human resources and budget plans, poorly handled management plans, etc.) (Hockings et al., 2000; Nolte et al., 2010). These concerns are also valid for Turkey, while Kurdoğlu and Çokçalışkan Avcıoğlu (2011) stated that there are serious problems in the development of basic management processes like planning, organization, coordination and control in most protected areas. The threats are mainly lacking of a well-defined protected area management system, inadequate technical experts, inconsistency with the international nature conservation system, mass tourism and pollution (Kuvan, 2012). According to Yücel and Babuş (2005) these are caused by poorly designed education programmes, legal gaps, difficulties in collecting data and particularly inappropriate land use. On the other hand, in the legal definition of national park in the National Parks Law No.2873 (Article 2) it has been stated that these are "parts of nature containing recreational and tourism areas". This has resulted with perceiving tourism development as a precondition of protected area design followed by inappropriate land use types, facilities and infrastructure (Yücel, 2005).

Ecological value analysis has been widely used in landscape planning studies, selection of nature conservation sites and their planning as well as species conservation programmes in the European and North American countries since 1960s in order to prevent aforementioned conflicts (e.g. Sukopp, 1970, 1971; Montag, 1976; von Haaren, 1980; Ammer et al., 1981; Ammer and Utschick, 1984; Wrbka et al., 2005; Stewart and Neily, 2008; Bradtka et al., 2010). State of the ecosystems and landscapes are analysed and assessed by considering their quantifiable characteristics such as; naturalness, rarity, integrity, functionality, stability, etc. The main motivation of using this method is to describe natural systems formed as a result of intertwined complex processes with their prominent features and determine their "ecological value" (Geyler, 2008). Although many parameters may be used for determining ecological value, they are mainly grouped under 3 categories as; (1) ecosystem-based parameters, (2) population- and particularly species-based parameters, and (3) anthropogenic-based parameters (Ammer and Utschick, 1984), parameters are selected due to the general characteristics of the site and planning goals (Wulf, 2001).

Considering the aforementioned problems and approaches, the main question "What to conserve/restore?" was tried to be addressed in order to (1) develop a new planning concept for determining nature conservation and restoration priority areas based on the basic principles of ecological value analysis and (2) develop a concept that can be changed and transformed according to the needs of different landscape types.

MATERIALS AND METHODS

Study Area

Yedigöller National Park (Bolu), which was selected as study area in this study, is located in Western Black Sea Region in Bolu between 31°44'-31°47' eastern longitudes and 40°55'-40°58' northern latitudes (Figure 1). The area was announced as national park in 1965 with the reason "presence of mixed forest plants as a whole in the same region" covering an area of 1631 ha and contains seven avalanche lakes. The altitude changes from 490 m to 1298 m. It lies within the northeastern euxin forest zone (Mayer and Aksoy, 1998) and mainly contains pure Oriental beech and a small amount of pure oak stands. The national park is also composed of mixed stands such as beech-fir, beech-oak, beech-oak-Black pine, beech-Black pine, beech-Black pine-Scots pine-fir, beech-Black pine-Scots pine, oak-beech, oak-Black pine and Black pine-oak stands. According to Tokcan (2015) there are 3 main plant communities (*Erica arborea-Quercus petraea, Rhododendron ponticum-Fagus orientalis* and *Fagus orientalis-Abies bornmülleriana*) and 7 sub-communities, while totally 202 taxa were determined in the study area from which 10 are endemics. Yedigöller National Park hosts annually 160 000 visitors in average mainly from April to November (Bolu Regional Directorate of Forestry 2017, oral. comm.). Most preferred recreational activities are picnicking, camping, trekking, photographing and line fishing, while these are mainly concentrated around lakes. Other focal sites in the park are monumental Black Pine and Kapankaya Panoramic Terrace (Figure 1).

Methods

The methodology used in the study basically contains the analyses performed in "ecological value analysis" and is composed of five main steps as; (1) selecting parameters as a base for the analyses, (2) generating data bases and base maps suitable for the parameters, (3) performing the analyses, (4) assessment and results, (5) preparing the map of nature conservation and restoration priority areas. In this study "biology and ecology based parameters" and "parameters based on various structural features of the forest" were selected in order to reflect the natural and cultural characteristics of the area instead of classical base maps such as slope, aspect, elevation, soil types, stand types and general flora and fauna lists. Ecological value analysis was performed with the assessment of 16 parameters under 4 main parameters, which are (1) naturalness (hemeroby degrees), (2) rarity (rarity of sub-plant communities and their aerial size, rarity of taxa in country and regional level and endemic taxa), (3) structural diversity (stand layerness, age, mixture type, mixture rate, canopy closure, number of biotope trees and their DBH -diameter at breast height-, deadwood amount, patch number of sub-plant communities and (4) species richness (number of tree, shrub and herbaceous taxa). These parameters were analysed by using relation matrices and direct scoring.

Sampling Design

Present base maps (hemeroby map and the map of sub-plant communities; Tokcan, 2015) and databases (Western Black Sea Forestry Research Institute GIS database) as well as the data gathered by field studies from totally 80 sample plots in two different levels were used in the analyses. Data related to stand structure and small structures were collected from 60 sample plots determined as the corner points of 1 km x 1 km UTM grid network from the whole area. All sample plots were non-randomly selected and sampling design follows the methodology used in hemeroby mapping in order to adapt data collected with field studies to the present maps and databases easily. Small structures (biotope trees and deadwood) were also determined in an area of nearly 300 m^2 as is applied in hemeroby mapping methodology (Grabherr et al., 1998) (Figure 2).

20 additional sample plots of 200 m x 200 m were identified around lakes in order to determine hemeroby degrees (degree of human influence on the natural environment; Grabherr et al., 1998) and sub-plant communities around lakes in detail, since anthropogenic use is mainly concentrated in this part of the park (Figure 2).

Data Assessment

Gathered data from 60 sample plots related to stand structure and small structures were first classified in a Microsoft Excel database file. Data related to sub-plant communities were also classified in a Microsoft Excel database and then assessed in JUICE program, while hemeroby data were first classified in Microsoft Access database and analysed in "hemprog" program. Maps of each parameter used in ecological value analysis were

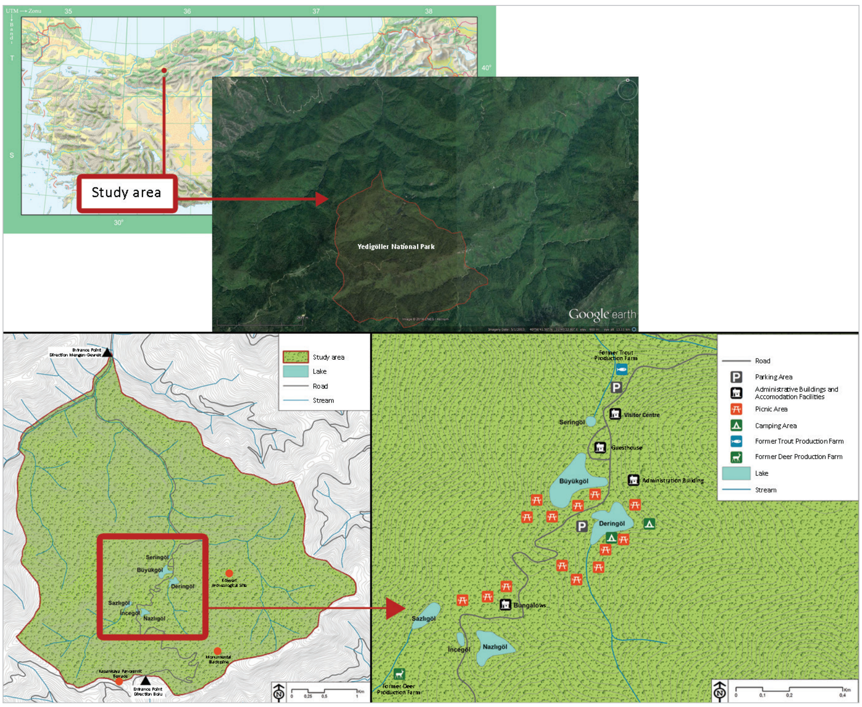

Figure 1. Location of the study area and main focal sites

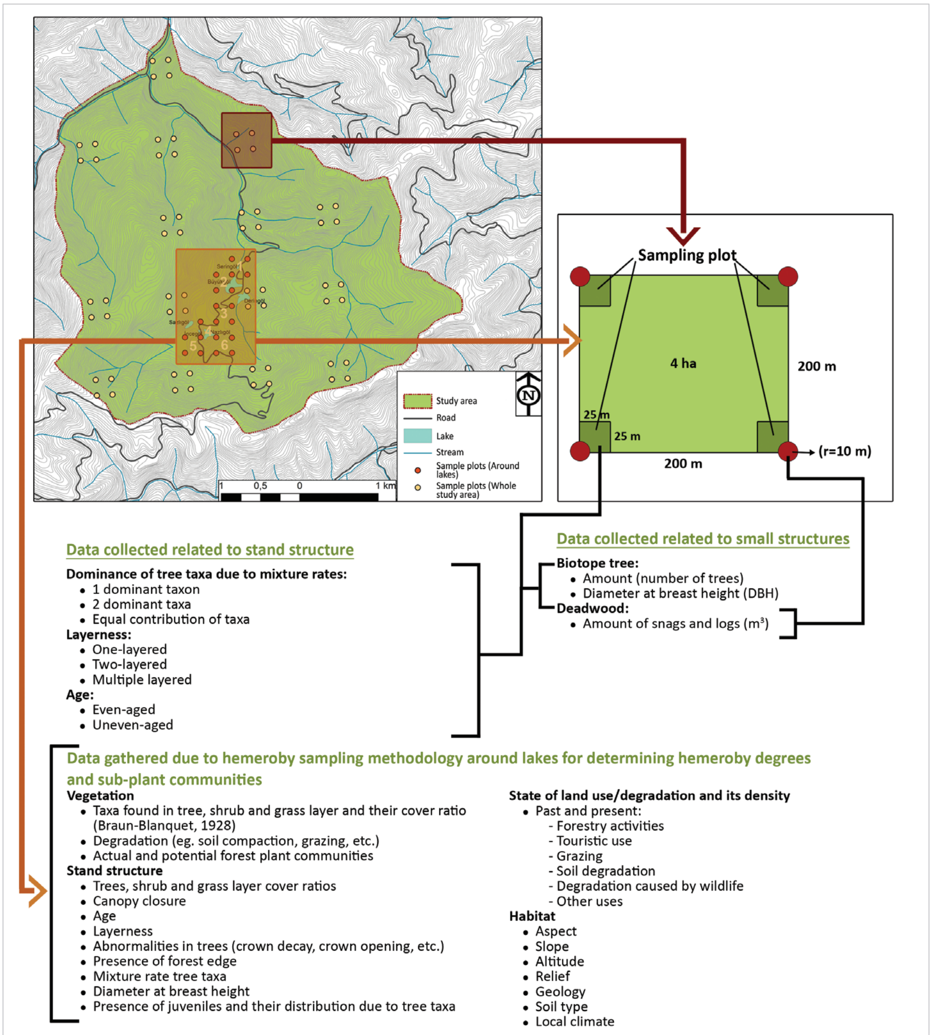

Figure 2. Sampling design to collect data related to stand structure and small structures as well as hemeroby degrees and sub-plant communities around lakes

prepared by taking the Yedigöller National Park Forest Stands Map as a layout and processed in ArcGIS 10.2 software.

The methodology in data assessment basically follows the general principles of the studies of Ammer and Utschick (1982, 1984), Stoffel (1992), Bastian et al. (2002) and Wrbka et al. (2007) (for detailed information, see Kırca, 2015). Following the preparation of the layout maps for ecological value analysis, parameters were classified as; (1) main parameters and (2) correction parameters. Main parameters were combined within each other with logical combination (S_1 to S_6 as shown in Figure 3) based on current literature and parameters were weighted due to their priority and importance identified according to the aims of the research as well as current knowledge (for S_1: i.e. Ammer and Utschick, 1982; Jefferson and Usher, 1986; Usher, 1986; Dzwonko and Loster, 1989; Verkaar 1990; Gaston, 1994; Idle, 1994; Kirby, 2004; Ploeg, 1994; Wulf, 1997; Wrbka et al., 2007 - for S_2: i.e. Preston, 1962; Schwartz and Simberloff, 2001; Gaston, 1994; Rodrigues and Gaston, 2002 - for S_3: i.e. Ammer and Utschick, 1982; Kirby, 2004; Honnay et al., 1999 - for S_4: i.e. Petermann and Seibert, 1979; Leibundgut, 1983; Duchiron, 2000; Gamfeldt et al., 2013 - for S_5: i.e. Ammer and Utschick, 1982; Atay, 1984; O'Hara, 1998, 2006; Çolak and Asan, 2010; Kerr et al., 2014 - for S_6: i.e. Winter et al., 2003; Hahn et al., 2005; Gürlich, 2009; Niedermann-Meier et al., 2010). Logical relation matrices were created for the combined parameters and scores from each combination were summed in order to calculate the nature conservation and restoration score (Figure 3).

Correction parameters were also combined with each other with logical combination (for C_1: i.e. Usher, 1994; Forman, 1995; Opdam et al., 1995; Gyllenberg and Hanski, 1997; Barsch et al., 2002; McGarigal, 2002; Piassens et al., 2004 and for C_2: i.e. Levins, 1969; Kareiva, 1990; Taylor, 1990; Hanski and Gilpin, 1997; Hanski, 1999; McGarigal, 2002) but also with direct scoring (for C_3: i.e. Jedicke, 1997; Kerr, 1997; Médail and Verlaque, 1997; Berg, 2001; Anderson, 2002; Brigham and Schwartz, 2003; Berg et al., 2008; Hampicke, 2013; Wittig and Niekisch, 2014 and for C_4: i.e. Prietzel, 1994; Grabherr et al., 1998; Vallauri et al., 2003; Hahn and Chris-

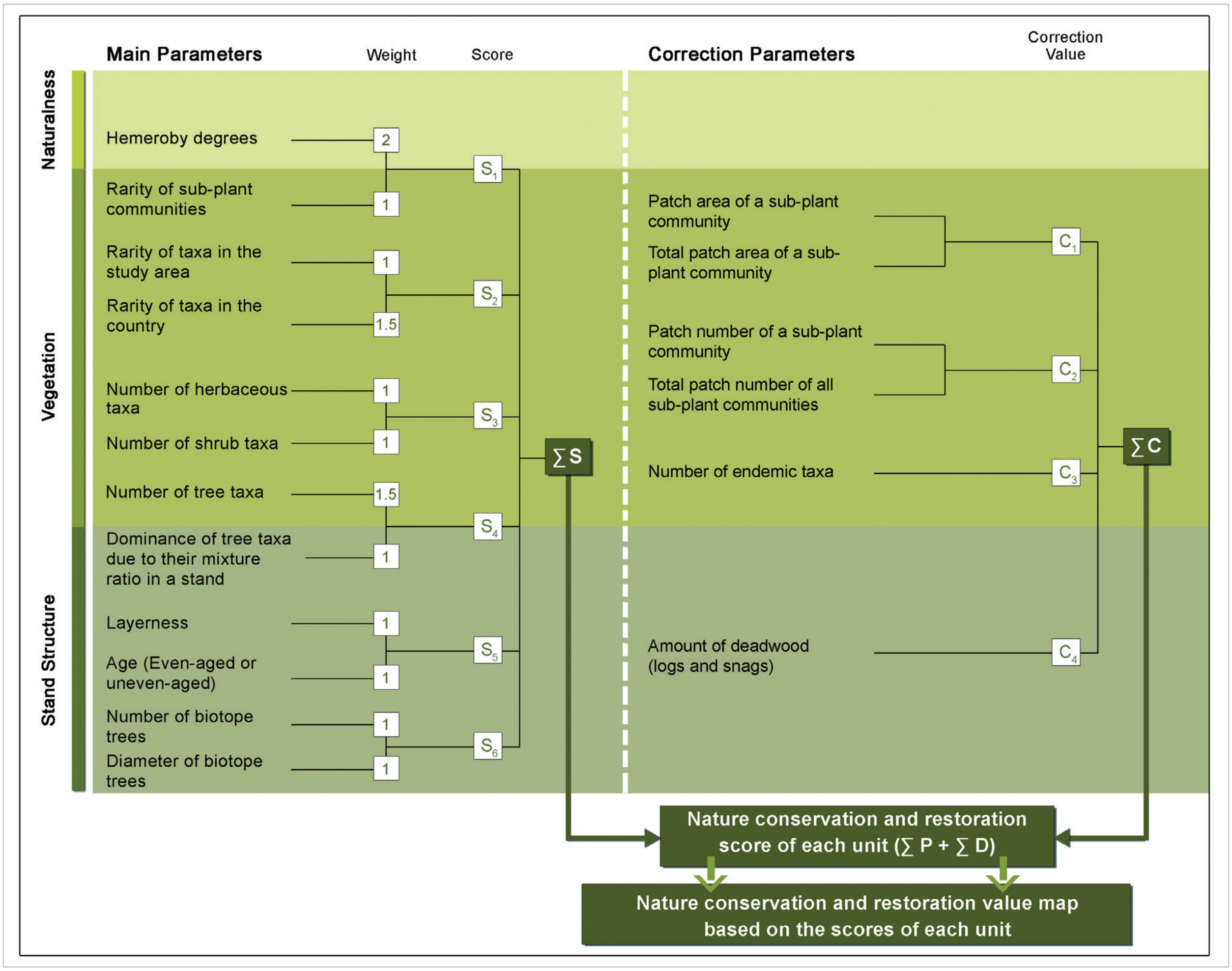

Figure 3. Methodology used for the calculation of nature conservation and restoration value in Yedigöller National Park

tensen, 2005; Çolak et al., 2011). Logical relation matrices were created for the combined parameters, while correction tables were created for the parameters assessed with direct scoring. As a result scores were summed and nature conservation and restoration value map was prepared as illustrated in Figure 4.

Maps of each parameter were transformed from vector maps to raster maps with a pixel resolution of 2 m x 2 m (unit) in order to calculate the nature conservation and restoration score of each unit. Then values in each unit were summed for the preparation of nature conservation and restoration value map in ArcGIS 10.2 (Figure 4).

RESULTS

The results of the assessment of main and correction parameters as well as nature conservation value map are given below.

Main Parameters

Hemeroby Degrees-Rarity of Sub Plant Communities

The detailed hemeroby analysis around the lakes revealed that hemeroby degrees range between β-euhemerob (3-far from natural) to ahemerob (9-natural). Together with the general hemeroby map (Tokcan, 2015), 0,3% of Yedigöller National Park was determined as β-euhemerob (3-far from natural), while 0,4% as α-mesohemerob (4-relatively far from natural), 0,2% as β-mesohemerob (5-relatively far from natural), 6.9% as α-oligohemerob (6-relatively far from natural), 6.8% as β-oligohemerob (7-semi-natural), 62.2% as γ-oligohemerob (8-close to natural) and 23.2% as ahemerob (9- natural) (Figure 5a).

Two sub plant communities were determined around the lakes as; (1) *Erica arborea-Quercus petraea/Pinus nigra* sub-community and (2) *Carpinus betulus* sub-community. After combining the map of sub plant communities of Tokcan (2015) with the results of this study, rarity degrees of *Erica arborea-Quercus petraea/Pinus nigra* sub-community of *Erica arborea-Quercus petraea* community, typical sub-community and *Pinus nigra* sub-community of *Rhododendron ponticum-Fagus orientalis* community were found as "very common", while typical sub-community of *Erica arborea-Quercus petraea* community, *Carpinus betulus* sub-community of *Rhododendron ponticum-Fagus orientalis* community and typical sub-community of *Fagus orientalis-Abies bornmülleriana* community were found as "rare" and *Pinus syl-*

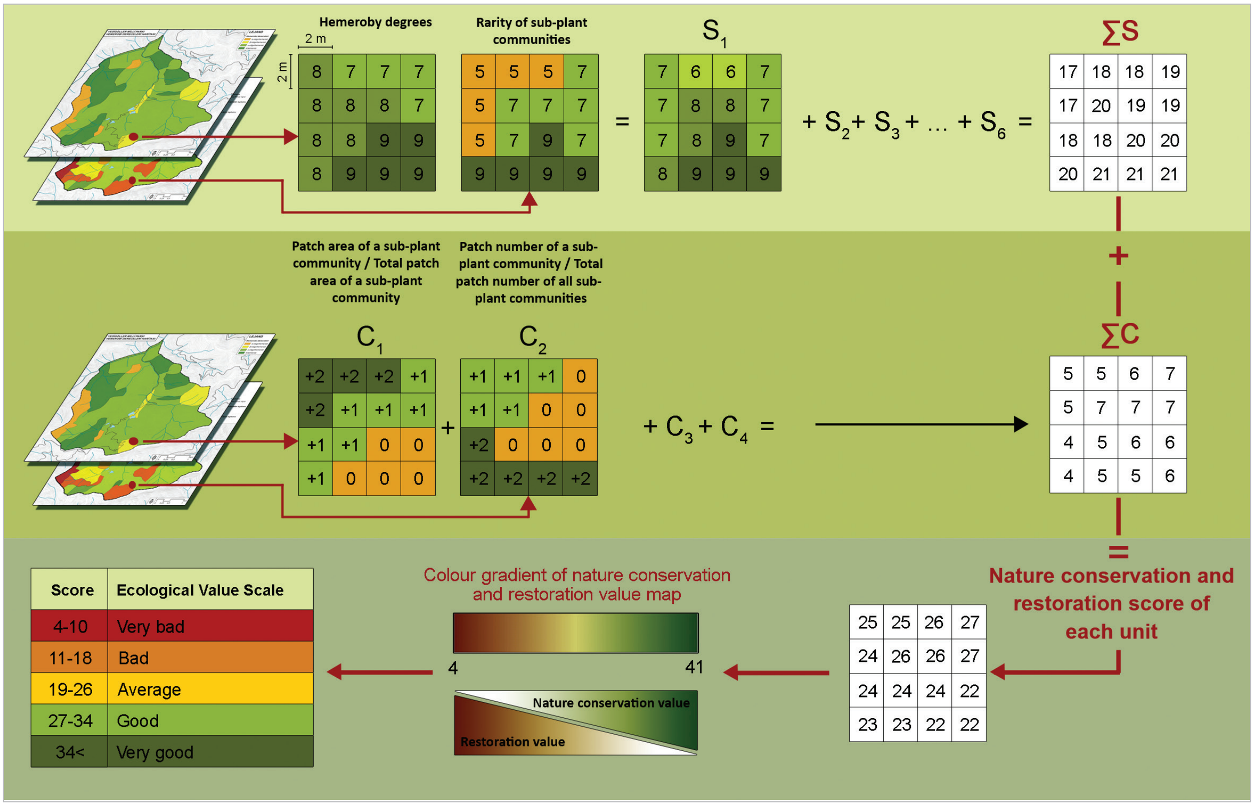

Figure 4. Steps followed by the preperation of nature conservation and restoration value map

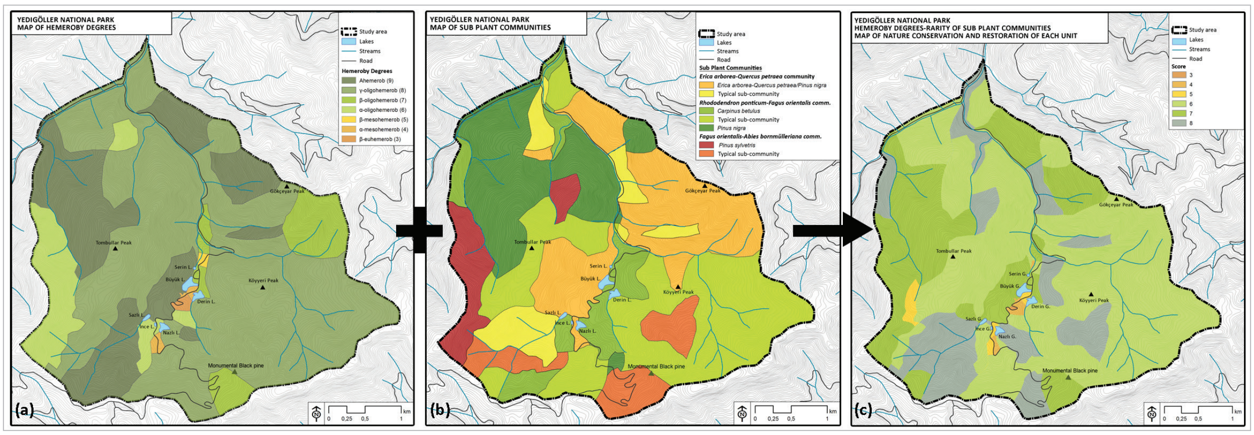

Figure 5. a-c. Yedigöller National Park (a) Map of hemeroby degrees, (b) Map of sub plant communitites and (c) Map of nature conservation and restoration score of each unit

vestris sub-community of *Fagus orientalis-Abies bornmülleriana* community was found as "very rare" (Figure 5b).
The resulting map in Figure 5c shows the nature conservation and restoration scores ranging between 3 to 8.

Rarity of Taxa in the Study Area-Rarity of Taxa in the Country
Totally 224 plant taxa determined in the study area were classified into 4 groups according to their rarity in the study area, while 3.8% (8 taxa) of the taxa were grouped as very common, 13.9% (31 taxa) as common, 33.8% (75 taxa) as rare and 48.5% (108 taxa) as very rare. These taxa were represented in 5 groups due to their presence in the sample plots in Figure 6a. According to this map, rarity rate "very rare taxa 2≥ " has the greatest share with 33% (529.26 ha). It is followed by "very rare taxa 2< " with a share of 29% (466.51 ha), "rare taxa 2< " with a share of 25% (411.35 ha), "common taxa" with a share of 7% (118.06 ha) and "rare taxa 2≥ " with a share of 6% (100.1 ha).

Unlike the rarity rates of taxa in the study area, 30.4% (68 taxa) and 63.8% (143 taxa) of 224 taxa were determined as very com-

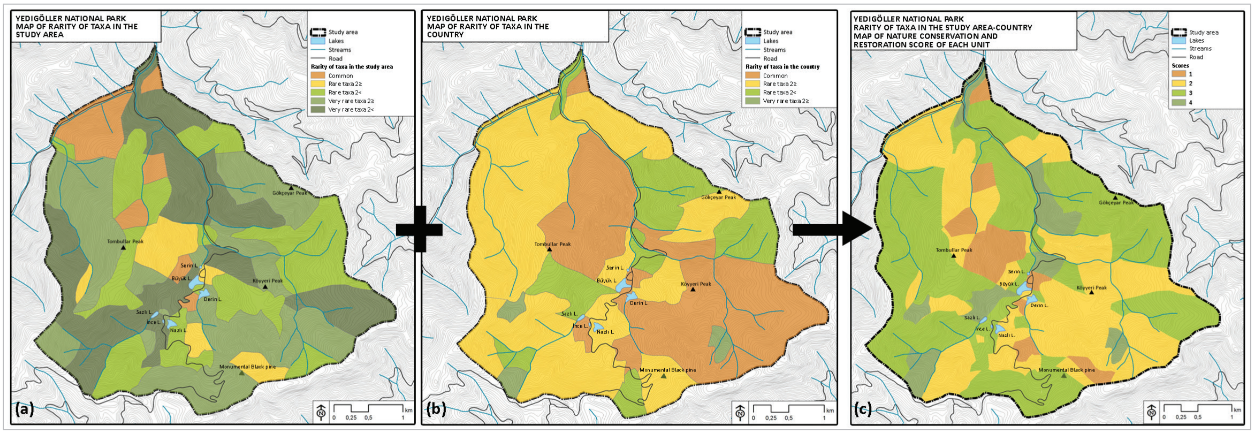

Figure 6. a-c. Yedigöller National Park (a) Map of rarity of plant taxa in the study area, (b) Map of rarity of plant taxa in the country and (c) Map of nature conservation and restoration score of each unit

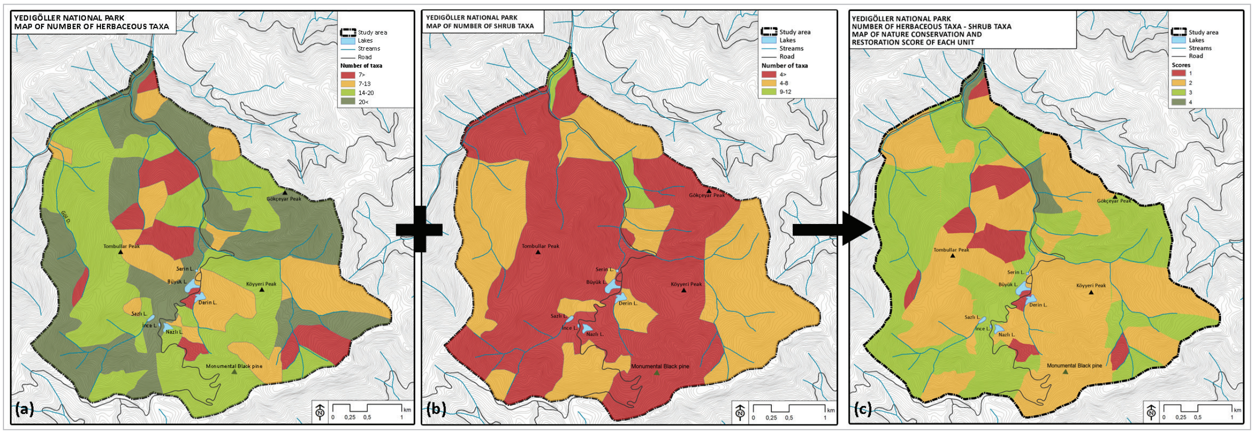

Figure 7. a-c. Yedigöller National Park (a) Map of number of herbaceous taxa, (b) Map of number of shrub taxa and (c) Map of nature conservation and restoration score of each unit

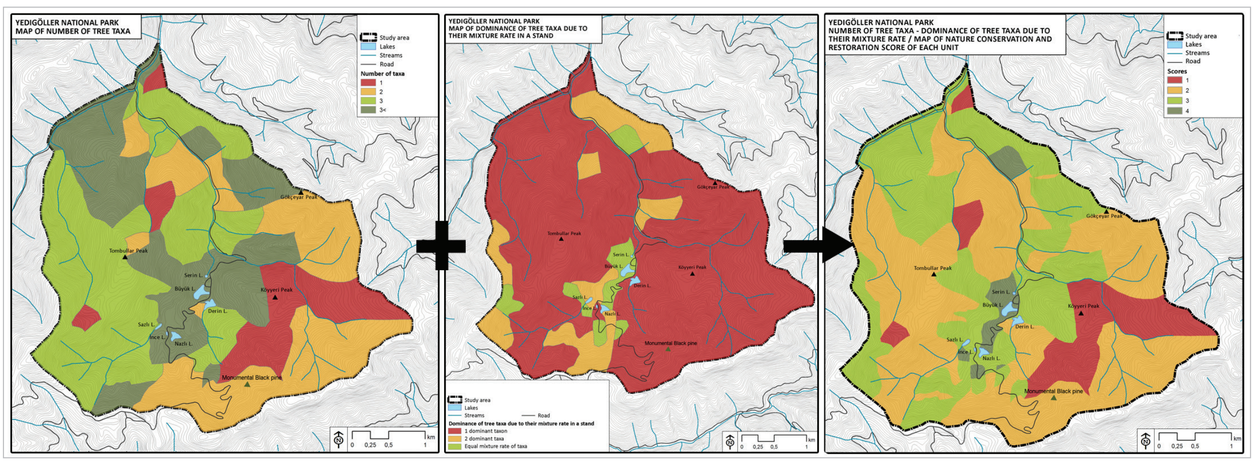

Figure 8. a-c. Yedigöller National Park (a) Map of number of tree taxa, (b) Map of dominance of tree taxa due to their mixture rate in a stand and (c) Map of nature conservation and restoration score of each unit

mon and common in the whole country, respectively. Only 4.9% (11 taxa) of the taxa were grouped as rare and 0.9% (2 taxa) as very rare. These taxa were represented in 4 groups due to their presence in the sample plots. According to the map (Figure 6b),

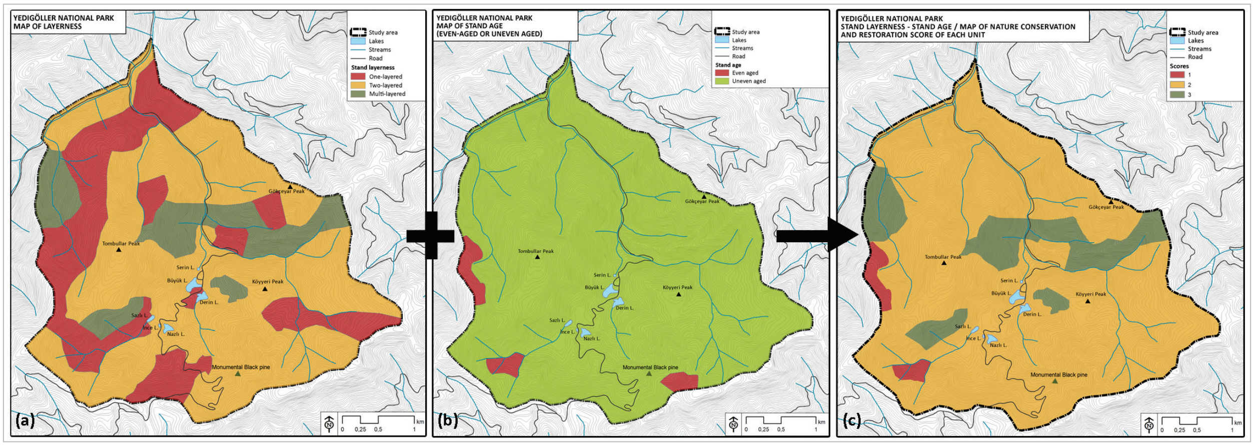

Figure 9. a-c. Yedigöller National Park (a) Map of layerness, (b) Map of stand age (even-aged or uneven aged) and (c) Map of nature conservation and restoration score of each unit

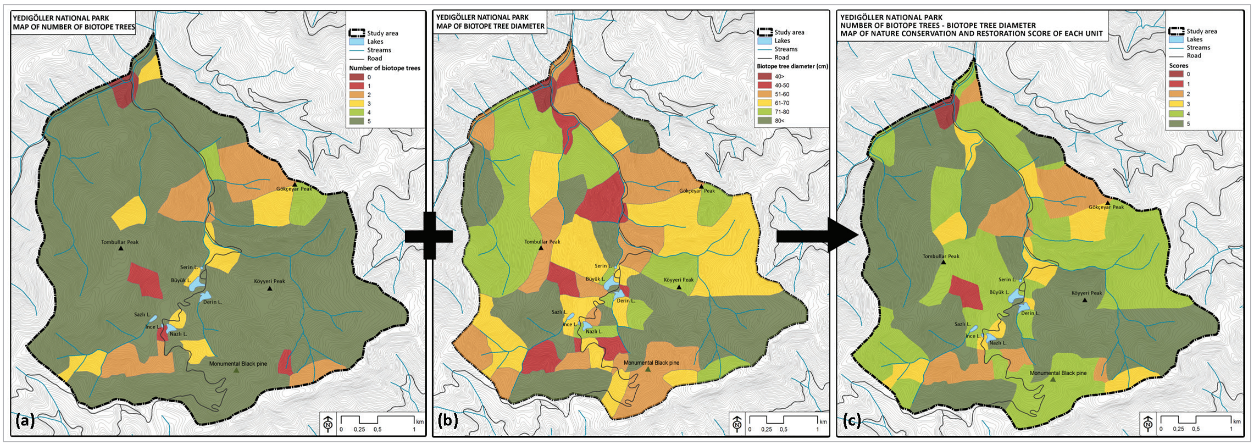

Figure 10. a-c. Yedigöller National Park (a) Map of number of biotope trees, (b) Map of biotope tree diameter and (c) Map of nature conservation and restoration score of each unit

rarity rate "rare taxa 2≥ " has the greatest share with 47% (769.44 ha). It is followed by "common" with a share of 35% (559.14 ha), "rare taxa 2< " with a share of 16% (264.25 ha) and "very rare taxa 2≥ " with a share of 2% (32.45 ha) (Figure 6b).

The resulting map in Figure 6c shows the nature conservation and restoration scores calculated according to the rarity of taxa in the study area and in the country ranging from 1 to 4.

Number of Herbaceous Taxa-Number of Shrub Taxa

Herbaceous taxa were classified into 4 groups due to their presence in the sample plots. Accordingly, number of herbaceous taxa is 7> in 9% (141.94 ha) of the area, while it is 7-13 in 17% (279.82 ha), 14-20 in 40% (654.22 ha) and 20< in 34% (550.04 ha) (Figure 7a).

Number of shrub taxa was represented with 3 groups, which are 4> in 60% (975.47 ha), 4-8 in 38% (618.92) and 9-12 in 2% (31.1 ha) of the study area (Figure 7b). The final map in Figure 7c shows the distribution of nature conservation and restoration scores ranging between 1 and 4.

Number of Tree Taxa-Dominance of Tree Taxa Due to their mixture Rate in a Stand

Tree taxa were classified into 4 groups due to their presence in the study area. As a result, 1 tree taxa was found in 12% (186.96 ha) of the study area, while 2 taxa was found in 26% (426.54 ha), 3 taxa in the 35% (586.66 ha) and 3< in 27% (443.51 ha) of the study area (Figure 8a).

In 83% (1346.79 ha) of the study area 1 tree taxa is dominant. Rest of the stands are composed of either 2 dominant tree taxa (12%-204.33 ha) or equal mixture of tree taxa (5%-74.38 ha) as shown in (Figure 8b). The resulting map in Figure 8c shows the nature conservation and restoration scores ranging from 1 to 4.

Layerness-Age

The results show that 26% (418.16 ha) of the study area is composed of one-layered stands, while 61% (998.76 ha) of two-layered stands and 13% (208.57 ha) of multi-layered stands (Figure 9a). On the other hand, 97% of the area is composed of uneven-aged stands and 3% (43.29 ha) of even-

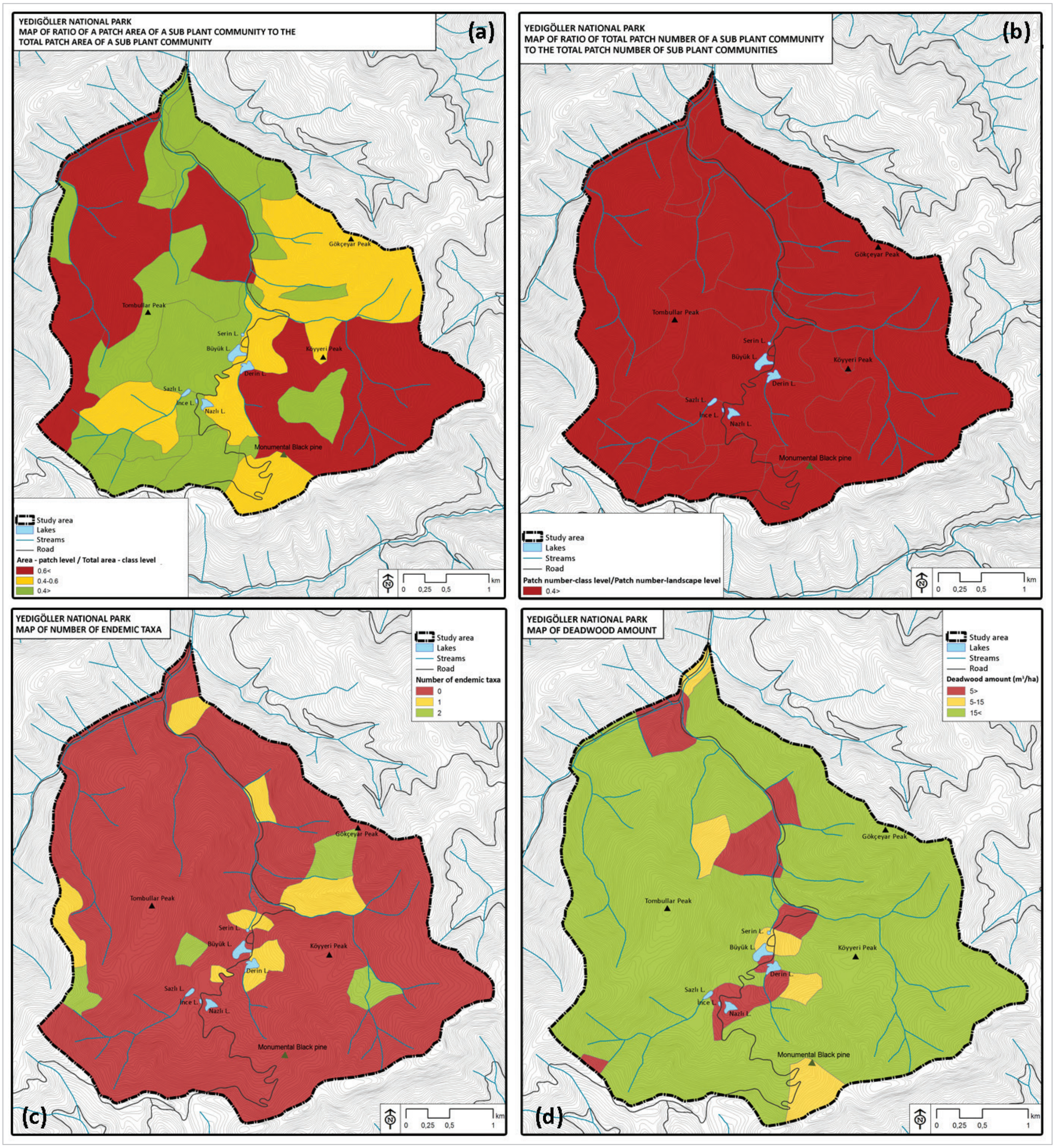

Figure 11. a-d. Yedigöller National Park (a) Map of ratio of a patch area of a sub plant community to the total patch area of a sub plant community, (b) Map of ratio of total patch number of a sub plant community to the total patch number of sub plant communities, (c) Map of number of endemic taxa and (d) Map of deadwood amount

aged stands (Figure 9b). The final map shows the distribution of nature conservation and restoration scores ranging from 1 to 3 (Figure 9c).

Number of Biotope Trees-Diameter of Biotope Trees

In 82% (1329.44 ha) of the study area 5 biotope trees were found. Rest of the area mainly contains 2 (8%-134.86 ha) or 3 (6%-93.71 ha) biotope trees as shown in Figure 10a. Diameter of biotope trees in the study area were classified under five groups, while tree diameter class of 80 cm< covers 27% (444.76 ha) of the study area. Diameter class of 71-80 cm was found in 22% (352.76 ha), 61-70 cm in 24% (384.04 ha), 51-60 cm in 20% (329.8 ha), 40-50 cm in 6% (101.02 ha) and 40 cm> in 1% of the study area (Figure 10b). The resulting map in Figure 10c shows the nature conservation and restoration scores ranging from 1 to 5.

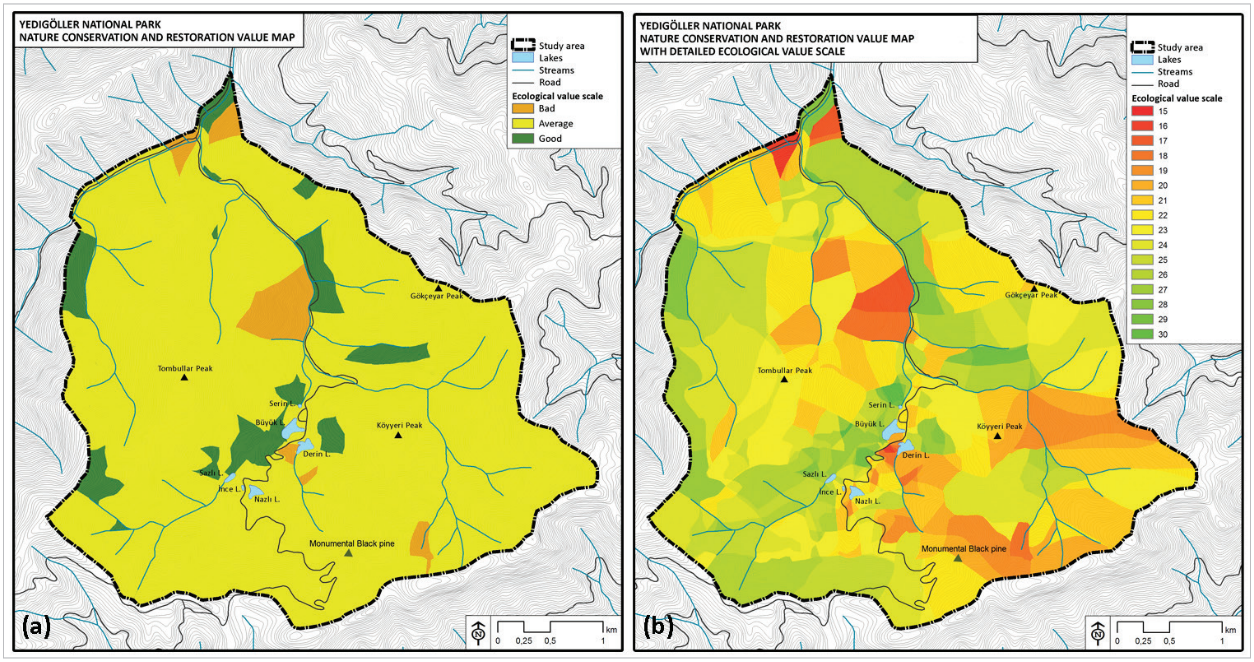

Figure 12. a, b. Yedigöller National Park (a) Nature conservation and restoration value map and (b) Nature conservation and restoration value map with detailed ecological value scale

Correction Parameters

The results of the ratio of a patch area of a sub plant community to the total patch area of a sub plant community were classified in 3 groups. The areas with a ratio of 0.6< cover 35% (574.05 ha) of the study area, which have the lowest ecological value. The areas with a ratio of 0.4-0.6 cover 23% (376.29 ha) of the study area, while the areas with highest ecological value represented with 0.4> cover 42% (675.24 ha) of the national park (Figure 11a).

Only 1 group was determined as the ratio of total patch number of a sub plant community to the total patch number of sub plant communities, which is 0,4> (Figure 11b). On the other hand, 8 endemic taxa were detected in the study area and were classified due to their presence in sample plots. As a result, 2 endemic taxa in 4% (60.37 ha) and 1 endemic taxon were found 6% (102.69 ha) of the study area (Figure 11c). Finally the amount of deadwood was found as 15< m^3/ha (highest ecological value) in 87% (1423.8 ha) of the study area, while areas with 5-15 m^3/ha and 5> m^3/ha have a smaller share of 5% (77.07 ha) and 8% (124.62 ha), respectively (Figure 11d).

Nature Conservation and Restoration Map

As a result of the assessment of main and correction parameters, 3 ecological value classes were determined as "bad", "average" and "good". 90% (1463.6 ha) of the study area was characterised as average, while 6% (105.13 ha) as high and 4% (56.76 ha) as bad as shown in Figure 12a. However, ecological value scores were given in detail in Figure 12b ranging between 15 and 30.

RESULTS AND DISCUSSION

Ecological value analysis has been widely applied in concepts generated by selecting suitable site-specific parameters since years particularly in western countries in landscape planning as well as selection and planning of nature conservation areas (Sukopp, 1970, 1971, 2004; Wilmanns et al., 1978; Marks, 1979; Von Haaren et al., 1980; Ammer et al., 1981; Ammer and Utschick, 1982; Stoffel, 1992; Alonso and Falero, 1995; Czeranka and Peithmann, 1997; Bastian, 1999; Brändli, 2001; Wrbka et al., 2005; Stewart and Neily, 2008; Bradtka et al., 2010). In this study parameters have been selected considering the general ecological character of the area and following suggestions related to ecological value analysis have been made:

Ecological value analysis may be applied in small scale (Ammer and Utschick, 1982), as well as in country scale (Wrbka et al., 2005). Thus, selection of parameters used in the analysis should be performed with great care. On the other hand, usual data layers like slope, aspect, altitudinal classes, soil types, stand types and general flora and fauna lists are generally used in many landscape planning practises applied in forest areas in Turkey. However many biological based important parameters have either not been used or the relation between them has been merely recognised. On the contrary, stands regarding the parameters commonly used in the studies among Europe, selected parameters are mainly based on the biological and ecological characteristics of the study area as well as various qualities of the forest. Therefore, a wide range of parameters were used related to naturalness, vegetation and stand structure in order to develop a site-specific and multidimensional analysis methodology in this study. As in this study, numerous new parameters may be used in ecological value analyses applied in forests, while they should be regarded as replaceable tools by new parameters and matrices may be easily modified and adapted to different situations. Some layouts used in this study, i.e. map of hemeroby degrees and plant societies, contains biological and ecological sub-parameters which strengthen the results of the analysis. In many studies it is highly recommended to use much parameters as possible as the landscape structure gets complicated (Braun-Blanquet, 1964; Margules et al., 1991; Riedel and Lange, 2002; von Haaren, 2004; Lindenmayer et al., 2006). Thus, use of such maps (e.g. biotope maps) are highly recommended in further analyses.

The results of ecological value analysis applied in Yedigöller National Park were presented in two different ways. The general framework of planning decisions may be rapidly formed by using both of those result maps (Figure 12), whch provide a more clear picture about the ecological value of the area. On the other hand, maps of each parameter (Figure 5-11) provide detailed knowledge and database on the landscape and may be used as supportive layouts by taking specific decisions as well as during the monitoring process after planning.

In this study, parameters were combined with logical relation matrices and weighted due to the literature on landscape ecology and landscape analysis as in Wrbka et al. (2005). Each group of parameter has been accepted to carry equal importance for nature conservation. Methods of multi-criteria decision making processes like Analytical Hierarchy Process, PROMETHEE, ELECTRE, etc. may be used in further studies in order to assess the differences in results of various methods.

The results of ecological value analysis may be used as layouts for landscape planning studies, however these analyses should be repeated for monitoring the success of the planning and natural dynamics in the long term. For example, in U.S.A. (Oakley et al., 2003) and EU member countries (Leverington et al., 2010) such procedures are repeated every 5-10 years in protected areas.

The forms filled for each sample plot may be used as bases with regard to the selection of suitable techniques in nature conservation and restoration practises to be applied in zones in the required areas and for the monitoring of the implementations in the long term.

Based on the findings of this study a zoning plan may be offered as classifying 65% of the national park as core area. The rest may be specified as buffer zone and transition zone. The following suggestions are offered to be considered when preparing a landscape plan for Yedigöller National Park:

The area of the national park might be broadened by determining alternative attraction points for recreational activities like picnic, camping, trekking, biking, etc. Thus, actual degradation around lakes caused by intensive recreational use would be prevented by creating alternative low-intensity recreational uses.

Further panoramic view terraces might be built in addition to the Kapankaya Panoramic View Terrace located near the south entrance of the area, while visitors would be invited to these points instead of lakes.

Eco-tourism and nature education activities might be promoted on the buffer zone and transition zone of the national park, which may be located on the managed forests around the actual border of the national park, since these forests do also represent the mixed forests characteristic to the region and contain diverse wildlife.

Monumental trees, biotope trees, areas rich in deadwood amount and contain species rich habitats (Beşkardeş, 2010; Anonymous, 2013) may be considered when designing trekking and biking routes in order to allow visitors meet different habitats and learn about their value.

Long-term management plan of the national park should be prepared to cover issues on general structure of the area and predetermined plan targets, nature conservation and forestry activities to be applied in each management zone, species and habitat conservation and restoration activities, uses and permits, infrastructure network, education and public relations, recreation and research opportunities and further details.

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Original Article

The effects of trekking activities on physical soil properties in the Bolu-Aladağ fir forests

Bolu-Aladağ göknar ormanlarında doğa yürüyüşü faaliyetlerinin bazı fiziksel toprak özelliklerine etkisi

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ABSTRACT

In this work, we study the effects of trekking on the soil physical properties in the Turkish Bolu-Aladağ fir forests. One hundred people walked in a straight line in the case study area, and their effects on a number of soil physical properties, such as litter fall thickness, soil bulk density, soil moisture, and soil compaction, were investigated. The study comprised three replicates over two tracks in two consecutive years. The thickness of the surface litter fall (mm) was measured and its amount determined in (gr/m^2) as the dry weight of the soil samples collected in the sampling area. Soil bulk density (g/L) was measured using cylindrical samples. Soil moisture (%) was determined based on the difference between the fresh and dry weights. The results indicate that the surface litter thickness decreased on trekking routes (r=0.568), and the fresh (r=0.440) and dried (r=0.423) soil bulk densities increased. However, there appeared to be no effect on soil moisture. Compared to the control samples, an average of 14% compaction was detected in trampled soils as a result of human pressure. Furthermore, the physical effects of trekking caused compaction of the litter fall and soil. As a result, such activities could lead to a decrease in soil infiltration capacity causing soil erosion and degradation in the future.

Keywords: Ecotourism, litter fall, soil bulk density, soil compactness, and soil moisture

ÖZ

Bu çalışma, Bolu Aladağ göknar ormanlarında, doğa yürüyüşlerinin toprağa etkisini araştırmak için yapılmıştır. Çalışmada 100 kişi ölçüm alanından tek sıra halinde yürümüş, doğa yürüyüşünün ölü örtü kalınlığı, toprak hacim ağırlığı, toprak nemi ve toprak sıkışması gibi fiziksel özelliklere etkisi incelenmiştir. Çalışma iki yıl peş peşe, iki ayrı parselde ve üçer tekerrürlü olarak yapılmıştır. Ölü örtü kalınlığı (mm) örnekleme sırasında ölçülerek, miktarı (gr/m^2) 25cm*25cm alandan toplanan örneklerin kuru ağırlığına bağlı olarak belirlenmiştir. Toprak hacim ağırlığı (g/L) hacim silindirleri kullanılarak, toprak nemi (%) de taze ve kuru ağırlık farkından yararlanılarak belirlenmiştir. Yapılan ölçümler ve değerlendirmelerin sonucunda; doğa yürüyüşü yapılan alanda ölü örtü kalınlığının azaldığı (r=0,568), taze (r=0,440) ve kurutulmuş (r=0,423) toprak yoğunluğunda artışa neden olduğu belirlenmiştir. Ancak toprak nemi üzerinde etkisi görülmemiştir. Kontrol alanına göre kıyaslandığında çiğnenen alan toprağında ortalama %14 oranında sıkışma meydana geldiği bulunmuştur. Doğa yürüyüşü esnasında çiğnenen toprakta meydana fiziksel etkiler ölü örtüde ve toprakta sıkışmaya neden olmuştur. Dolayısıyla toprağın geçirgenlik kapasitesini düşürecek, devamında yabanlaşmaya ve erozyona yol açabilecektir.

Anahtar Kelimeler: Ekoturizm, ölü örtü, toprak hacim ağırlığı, toprak sıkışması, toprak nemi

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INTRODUCTION

Tourism, crucial for the economic development of many countries, has gained impetus over the last few decades. Any investment in the tourism sector creates action and dynamism in the economy and truly affects the level of a country's economy in various ways. In association with the rapid urbanization of recent years, the desire to access and be involved more in tourism activities in natural areas has increased. Thus, the concept of ecotourism was developed and is it now used in the regular tourism sector to satisfy the increasing number of people who want to experience nature (Erdoğan and Erdoğan, 2005).

The principle reason for the gradual increase in natural tourism and increased interest in life in the villages (Dönmez et al., 2015) is the economic and ecological potential in those areas (Koçoğlu, 2008). There are several reasons why ecotourism is concentrated in protected natural areas and some of these may be the unique natural and cultural resources themselves. Therefore, rules are necessary, limits need to be set, and there must be vigorous control of any activities that may have a detrimental effect on nature and the environment (Mol, 1979).

The concept of ecotourism embraces many factors including social and cultural activities. The World Conservation Union (IUCN) defines ecotourism as the "*Environmentally responsible travel to natural areas, in order to enjoy and appreciate nature (and accompanying cultural features, both past and present) that promotes conservation, has a low visitor impact and provides for the active beneficial socio-economic involvement of local peoples" (IUCN, 2001)*. Officially, the Ministry of Culture and Tourism defines ecotourism as encompassing many activities such as upland tourism, ornithology (bird watching), photo safaris, water sports (canoeing), farming tourism, botanical tourism (plant identification), cycling tours, horse riding, camping, caving, mountain tourism, and trekking (Özgen, 2010; Url, 1).

The United Nations Sustainable Development Commission declared 2002 as the International Year of Ecotourism and appointed the World Tourism Organization in charge of the task (Koçoğlu, 2008). Similarly, the United Nations declared 2002 as the International Year of Mountains (Erdoğan and Erdoğan, 2005).

Besides their positive contributions, ecotourism activities come with some shortcomings that need to be taken into consideration. In addition to the identification of the fauna and flora of the region where the ecotourism is planned, uncovering the likely environmental effects necessitate and, in fact, contribute to the determination of the natural resource capacity. Erroneous selection of location and overuse of areas beyond their carrying capacity causes detrimental effects on the environment resulting in the degradation of natural resources during the realization of ecotourism activities (Kaypak, 2010). If the natural resource inventory is completed in our country, the carrying capacity of each region would be determined, thus studies related to ecological productivity would be based on solid research. In fact, it is necessary to determine the ecological effects of ecotourism and take these into account during the planning phase.

Bolu province, having some of the important natural resources in the western Black Sea region, has remarkable ecotourism capacity in the Aladağ region spread over the Köroğlu continuous mountains (Türker, 2013). The Bolu forests offer splendid and diverse fauna and flora, each season has its own beauty and provides tremendous capacity for ecotourism activities (Url, 2). However, these activities should be thoroughly planned in order to unlock the potential capacity of the region. Effective planning requires an immediate and thorough inventory of the natural resources and analysis of the ecological impacts.

This study focuses on the effects of trekking, one of the most widely exercised ecotourism activities, on forest soils. Specifically, we investigated the possible effects of trekking on some of the physical characteristics and properties of soils in the important Bolu-Aladağ fir forests of the western Black Sea region.

MATERIALS AND METHODS

The Study Area

The study area is located within the Şerif Yüksel Research Forest, Aladağ Forest, south Bolu province. The sample points were established in a forested area with relatively gentle relief (slope <5%) and a southern aspect at elevations between 1500 and 1550 m. The extent of the area was (ED50 datum) 40°35′58.62″N-31°39′34.17″E and 40° 37′ 57.97″N-31° 35′ 31.02″E (Figure 1).

The trekking route starts from the corner of the Bolu-Seben highway in Aladağ then continues through the Değirmenözü Plateau, the center of the Aladağ Forest, the Kızık, Doğancı Village and Avşar Plateaus, and ends in the high Hıdırşeyh Plateau. The total route length is 10 km. Existing paths and forest roads were used during the trekking experiment, however, trekking did take place in forested areas when the sample points were located within them.

Method

During May 2010, two strips were determined for measurement along the main trekking routes. One of them is Avşar Plateau, the other is "International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests" (ICP) plot side. The trekking strips were designed to be 100 m long and 1–2.5 m wide under a pure fir canopy and take walkers in single file. The edges of the strips were marked with tape to make it easy to follow the sampling line (Figure 2).

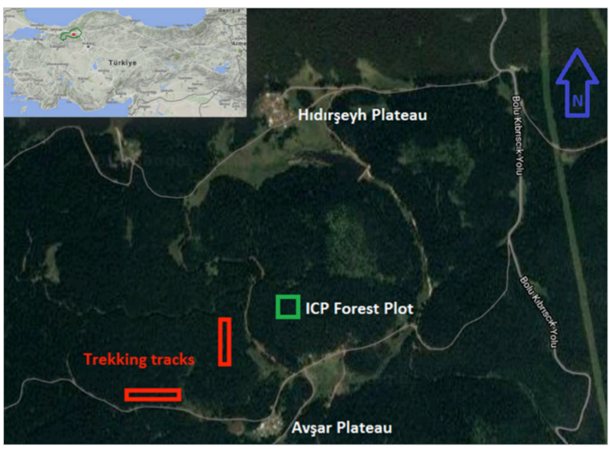

Figure 1. Map of study area (Google maps)

For sampling purposes, trekking activities were organized during June in both 2010 and 2011. One hundred people walked the same sample trekking strip in both years. As soon as the trekking activity finished, litter fall and soil samples were taken from both the sample trekking strips and control areas located in the near vicinity, and the effects of trekking on soil properties were determined.

Three samples of litter fall and soil were taken from the same depth at three different points within the trekking strips and the same from the control areas. To determine the level of soil compactness, cylinders of soil, 5 × 5 cm in length and diameter and with a pure constant bulk density, were taken from the upper soil layer (Figure 3). The same parameters were applied to additional samples taken for use in other analyses. All the soil samples were labeled and packed in a way that maintained their natural moisture levels, they were then transported to a lab for testing and soil moisture analysis. The litter fall samples were taken using 25 × 25 cm quadrants and their thicknesses were measured (Figure 3).

The oven dry weights of the cylinder samples (105°C, 24 hours) were used to determine the level of soil compaction. The soil moisture and water contents were identified from the same cylinder samples by measuring both the fresh and dried net weights of the samples. Then, both weights were divided by the cylinder volume to determine the soil bulk density (g/L). The thickness of the litter fall was measured directly in the forest. The amount of litter fall per unit area (g/m^2) was determined based on the dried weight of the samples (65°C, 24 hours). In 2010, the soil types in the sampling areas (distribution to unit diameters) were identified using the Bouyoucos Hydrometer method (Gülçur 1974; Kantarcı 2000).

SPSS statistical software was used to analyze the statistical relationship between the measurements and the laboratory results. The Pearson correlation analysis method was used to determine the relationships among all dependent and independent variables. Furthermore, one-way ANOVA was used to determine the effects of independent variables related to the research year and sampling area on the dependent variables related to the soil samples, at $p<0.05$ level of confidence.

Figure 2. Trekking in the designated measurement area

Figure 3. Sampling the soil and litter

Table 1. Correlation analysis of soil properties

	Litter Thickness (mm)	Litter Amount (g/m²)	Fresh Soil Bulk Density (g/L)	Dry Soil Bulk Density (g/L)	Soil Moisture (%)	Sand (%)	Clay (%)	Water Contents (g/L)	Compactness (%)
Year	0.144	0.119	0.088	0.140	-0.087	.a	.a	-0.036	0.154
Sampling area	0.144	0.253*	-0.392**	-0.272**	-0.185	0.747**	-0.068	-0.414**	-0.176
Strips area	-0.568**	-0.417**	0.440**	0.423**	-0.077	-0.162	0.743**	0.273**	0.471**
Litter Thickness (mm)	1	0.780**	-0.323**	-0.283**	-0.006	0.210	-0.532**	-0.243*	-0.359**
Litter amount (g/m²)	0.780**	1	-0.369**	-0.337**	0.027	0.223	-0.286	-0.256*	-0.330**
Fresh Soil Bulk Density (g/L)	-0.323**	-0.369**	1	0.903**	-0.007	-0.694**	0.681**	0.712**	0.433**
Dry Soil Bulk Density (g/L)	-0.283**	-0.337**	0.903**	1	-0.430**	-0.579**	0.671**	0.341**	0.504**
Soil Moisture (%)	-0.006	0.027	-0.007	-0.430**	1	0.196	-0.462**	0.688**	-0.231*
Sand (%)	0.210	0.223	-0.694**	-0.579**	0.196	1	-0.494**	-0.552**	-0.434**
Clay (%)	-0.532**	-0.286	0.681**	0.671**	-0.462**	-0.494**	1	0.190	0.684**
Water Content (g/L)	-0.243*	-0.256*	0.712**	0.341**	0.688**	-0.552**	0.190	1	0.123
Compactness (%)	-0.359**	-0.330**	0.433**	0.504**	-0.231*	-0.434**	0.684**	0.123	1

Correlations at * (p<0.05) and **(p<0.01) confidence levels.

Table 2. Variance analysis of soil properties by year

	2010	2011	Standard Deviation	p
Litter Thickness (mm)	16.6	19.2	0.9	0.176
Litter Amount (g/m²)	3635.0	3870.0	972.0	0.264
Fresh Soil Bulk Density (g/L)	1321.0	1351.0	162.0	0.407
Dry Soil Bulk Density (g/L)	854.9	889.3	121.0	0.187
Soil Moisture (%)	54.5	52.8	9.9	0.416
Water Contents (g/L)	467.0	461.0	74.0	0.737
Compactness (%)	4.2	8.9	15.0	0.147

RESULTS AND DISCUSSION

According to the correlation analysis: the trekking activities have a negative correlation with or effect on the thickness (r=–0.568**) and amount (r=–0.417**) of litter fall, and a positive correlation with the fresh weight of soil bulk density (r=0.440**), dry weight of soil bulk density (r=0.423**), water content (r=0.273**), and ratio of soil compaction (r=0.471**). The amount and thickness of litter fall show negative correlations with the fresh and dry weights of soil bulk density, the water content, and the rate of soil compaction (Table 1).

An increase in the amount of litter fall caused an increase in soil porosity and a reduction in weight. Soil bulk density showed a negative correlation with sand content and positive correlations with clay and water contents, and the rate of soil compaction. Furthermore, the rate of soil compaction is positively correlated with clay content and negatively correlated with sand content (Table 1).

The trekking activities took place in June in 2010 and 2011. An ANOVA test, carried out to determine the effects of trekking activities on the physical properties of soils in various years, revealed no apparent differences between the soil properties and the year (Table 2).

There are both similarities and differences in the soil properties of samples taken from two sampling strips. For example, there are differences (p<0.005) between the samples in terms of soil bulk density, and sand and clay content. However, litter thickness, soil moisture, clay content, and the rate of soil compaction seem to show similarities (Table 3).

When the soil properties of the samples from the trekking strips and the control areas were compared, all variables, except soil moisture and sand content, were found to be significantly different (p<0.05) (Table 4). The litter fall was squeezed during the trekking activities becoming 40% compacted, while a further 20% of the litter fall was ground down and dispersed to the soil. Both the fresh and dry bulk density of soil exposed to the trekking activities indicated a >10% increase. The amount of clay in the trekking and the control samples was found to be statistically different and the level of difference in the two sampling areas was less than 2%.

This work focuses on the creation of adequate information necessary for determining the effects of trekking, a widely exercised ecotourism activity, on forest soils. The trekking activities in fir forests caused a reduction in the level of litter fall by crushing, and increasing the soil bulk density and compactness. Jim (1987) carried out similar research in a rural park exposed to camping activity and found that soil trampling

Table 3. Variance analysis of soil properties based on sample area

	ICP Side	Avşar Plateau	Standard Deviation	p
Litter Thickness (mm)	16.7	19.2	8.5	0.176
Litter Amount (g/m²)	3476.9	3975.8	972.0	0.016
Fresh Soil Bulk Density (g/L)	1416.3	1287.3	162.0	0.000
Dry Soil Bulk Density (g/L)	915.7	848.8	121.0	0.009
Soil Moisture (%)	55.7	52.0	9.9	0.081
Sand (%)	40.7	44.5	2.6	0.000
Clay (%)	40.3	40.2	1.3	0.695
Water Contents (g/L)	500.6	438.5	74.0	0.000
Compactness (%)	10.2	4.9	15.0	0.096

Table 4. Variance analysis of the effect of trekking on soil physical properties

	Trekking Areas	Control Areas	Standard Deviation	p
Litter Thickness (mm)	13.3	23.0	8.5	0.000
Litter Amount (g/m²)	3373.0	4179.0	972.0	0.000
Fresh Soil Bulk Density (g/L)	1410.0	1268.0	162.0	0.000
Dry Soil Bulk Density (g/L)	926.0	825.0	121.0	0.000
Soil Moisture (%)	52.7	54.3	9.9	0.472
Sand (%)	42.2	43.0	2.6	0.344
Clay (%)	41.2	39.3	1.3	0.000
Water Contents (g/L)	483.4	443.3	74.0	0.009
Compactness (%)	14.0	0.0	15.0	0.000

caused degradation in soil structure, and a decrease in soil porosity, organic matter content, infiltration, and water holding capacity. The bulk density of the upper soil in areas used as skidding forest trails and therefore exposed to more pressure, was found to be 60% higher than in other areas (Makineci et al., 2007). Similarly, penetrometer resistance was measured as 50% higher in the upper soils of skidding trails due to compaction (Demir et al., 2010).

The main factors causing soil compaction are the power required for compaction, litter thickness, soil structure, size of granules, and soil moisture (Adams and Froehlich, 1981). In this study, an increase in litter thickness and the amount of sand present provided a soil structure that showed more resistance to compaction, yet an increase in clay content caused an increase in the rate of soil compaction. According to Pickering and Hill (2007), recreational activities in forests affect soil compaction, surface litter, and the hydrological balance. In general, 40% of the bulk density in an average forest soil is solid mass (minerals and organic matter), 25% is air, and 35% is filled with the water. Soil compactness refers to the increase in soil bulk density resulting from the degradation of soil structure due to exposure to external conditions or forces and the agglomeration of soil granules (Adams and Froehlich, 1981).

Significant changes were detected in the amount and thickness of surface litter between the trampled and natural areas. Research conducted at recreational sites in Belgrad forest indicated that the amount of surface litter was reduced to half on areas exposed to certain trampling activities compared with undisturbed areas (Çakır et al., 2010). Similarly, Demir et al., (2007) showed that on skidding trails in beech forests the amount of surface litter was reduced to half that in undisturbed forests. These results indicate that intensive use of forest areas for recreation and skidding activities affects the amount of surface litter more than trekking.

Soil compaction normally causes an increase in soil bulk density, degradation in soil porosity, changes in hydrological transmission and air perforation, and an increase in the physical resistance to roots (Turgut, 2012). Furthermore, microbial activity is lost to certain degree in compacted soil, which has a degraded structure in terms of aggregation and porosity. As a result, decomposition and mineralization of nutrients are affected (Hoorman et al., 2011). This situation causes a loss of soil productivity along with degradation and erosion.

There were no statistical differences between the measurements taken in the same areas in 2010 and 2011. However, a certain level of increase was observed in bulk density and rate of compaction in 2011. We believe that the trampling effects from the previous year continued in the following year. Soils exposed to compaction may recover over time (Thorud and Frissell, 1976). Turgut (2012) indicated that soils exposed to heavy compaction take a long time to recover.

When the sample points were compared with each other, the fresh and dry soil bulk density, and the water content were found to be higher (~10%) in the sample from the ICP side than from the sample located in Avşar Plateau. This could be attributed to the more granular soil structure from the 10% more sand in the Avşar Plateau sample; the clay content was the same in both areas. However, besides the changes in soil properties no significant difference in soil compactness was observed.

While an almost 10% increase in water content was observed in the trekking strip samples compared with the control samples, interestingly there were no significant differences in soil moisture. This can be attributed to the fact that soils continue to hold their water content, even though they lose porosity, during the shrinkage in granularity when exposed to a certain level of pressure. However, soil moisture decreases significantly in areas such as skidding trails heavily exposed to intensive trampling (Demir et al., 2007).

CONCLUSION

A widely practiced ecotourism activity, trekking can cause noticeable effects on the physical properties of soils, particularly when exercised by a large group of people. The principle direct effects are ground-down surface litter, soil compaction, and an increase in soil bulk density. There are also some indirect effects such as degradation in soil porosity, and changes in ground infiltration, water holding capacity, and aeration may be caused.

Large crowds of people taking part in activities that are not part of the natural process, such as trekking, have the potential to cause changes in the natural structure and dynamics of the landscape. One of the other environmental features impacted by trekking is the composition and structure of ground vegetation. Thus, it is recommended that new research needs to be designed to study and evaluate any impacts on the natural structure and dynamics. Other environmental features impacted by trekking include the forest wildlife and the microorganisms that mostly live under the surface litter. Further research is also needed to study the wildlife resources affected by any anthropogenic disturbance such as trekking.

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Original Article

Effect of heat treatment on the dimensional stability of ash (*Fraxinus angustifolia* Vahl.) wood

Dişbudak (*Fraxinus angustifolia* Vahl.) odununun boyutsal stabilizasyonu üzerine ısıl işlemin etkisi

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ABSTRACT

In this study, the effect of heat treatment on dimensional stability of ash (*Fraxinus angustifolia* Vahl.) wood, which naturally grows in Turkey, was investigated. Ash wood samples were subjected to the heat treatment process at different temperatures (120°C, 160°C, 190°C, and 210°C) and for different time periods (3, 6 and 9 h) in water vapor atmosphere. Water absorption, water repellent effectiveness, anti-swell effectiveness (ASE, TS 4084) and Attenuated Total Reflection - Fouirer Transform Infrared Spektrofotometre (ATR-FTIR) were performed on the test samples. Generally, although water absorption decreased with an increase in treatment temperature and time period, the mean of water repellent effectiveness and ASE increased. It was determined that decreases in the absorbance value of the peak belong to the -OH stretching vibration depended on heat treatment temperature increases. In particular, ASE increased to >40% with a rapid increase after 3 hours application of heat treatment at 190°C. The highest dimensional stability (58.4%) of ash wood was detected in the highest heat treatment temperature and time period (210°C and 9 h, respectively). Therefore, it was shown that the value and product quality of solid products produced from ash wood with heat treatment can be improved without the use of toxic chemicals.

Keywords: Ash wood, dimensional stability, ATR-FTIR, water absorption, water repellent effectiveness

ÖZ

Bu çalışmada, Türkiye'de doğal olarak yetişen dişbudak (*Fraxinus angustifolia* Vahl.) odununun boyutsal stabilizasyonu üzerine ısıl işlemin etkisi araştırılmıştır. Dişbudak örneklerine su buharı ortamında, farklı sıcaklık (120, 160, 190 ve 210°C) ve sürelerde (3, 6 ve 9 saat) ısıl işlem uygulanmıştır. Deney örnekleri üzerinde, su alma oranı (SAO), su itici etkinlik (SİE), genişlemeyi önleyici etkinlik (GET) ve ATR-FTIR analizleri gerçekleştirilmiştir. Genel olarak ısıl işlem sıcaklık ve süresinin artışı ile SAO'larında azalmalar meydana gelir iken, SİE ve GET değerlerinde artışlar tespit edilmiştir. Isıl işlem sıcaklığının artışına bağlı olarak, -OH gerilme titreşimine ait piklerin absorbans değerlerinde azalmalar tespit edilmiştir. Özellikle 190°C'de 3 saatlik uygulamada GET değerleri hızlı bir artış ile %40'ın üzerine çıkmıştır. Dişbudak odununun en yüksek boyutsal stabilite değerleri (%58,4), en yüksek ısıl işlem sıcaklık ve süresinde (210°C ve 9 saat) elde edilmiştir. Sonuç olarak, ısıl işlem uygulaması ile dişbudaktan üretilen masif odun ürünlerinin kalite ve değerlerinin zehirleyici kimyasallar kullanılmadan artırılabileceği görülmüştür.

Anahtar Kelimeler: Dişbudak odunu (*Fraxinus angustifolia* Vahl.), boyutsal stabilizasyon, ATR-FTIR, su alma oranı, su itici etkinlik

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INTRODUCTION

Heat treatment involves holding the wood between 100 and 250°C, either in a standard atmosphere, nitrogen (N), molecular nitrogen (N_2) or any other inert gas atmosphere for a period of time. Heat treatment processes have a significant place in the wood industry and many countries develop these procedures by utilizing different production parameters and methods (Vernois, 2000; Jamsa & Viitaniemi, 2001; Shi et al., 2007; Boonstra, 2008; Esteves & Pereira, 2009).

Heat-treated wood does not exhibit toxicity nor does it produce harmful effects on the environment. Therefore, heat treatment processes are considered as alternative protection methods as opposed to chemical impregnation and other modification methods (Yıldız et al., 2006). Wood modification techniques are designed to improve more than one property with a single treatment. The aim of thermal modification is to reduce the moisture exchange, i.e., to enhance the dimensional stability of wood and increase its resistance against wood decaying organisms (Poncsak et al., 2006; Kocaefe et al., 2008; Rowell et al., 2009; Sinković et al., 2011; Yalcin & Sahin, 2015). Moreover, heat treatment causes the equilibrium moisture content in wood to decrease, while increasing the depth of color and thermal insulation. On the other hand, wood becomes more brittle as a result of heat treatment. After the process, depending on the degree of heat treatment, the bending and tensile strengths of wood decrease (Kamdem et al., 2002; Hakkou et al., 2005; Repellin & Guyonnet, 2005; Şahin, 2014).

Heat treatment alters the chemical properties of wood as well. The deterioration starts with the hemicellulose (Yılgör, 1999). As the hygroscopic (water absorbing) property of hemicellulose is great, the reduction in the amount of hemicellulose content of heat-treated wood increases its dimensional stability (Tuong and Li, 2010; Şahin, 2014). In addition, the lignin softens and changes in the cellulose hydroxyl groups (-OH groups) take place with heat treatment (Bekhta and Niemz, 2003). As a result, in contrast to conventionally dried wood, the water absorption capacity of wood treated at high temperatures is reduced (Kocaefe et al., 2007). In studies carried out with *Pinus pinaster* and acacia wood, it was reported that heat treatment applied at temperatures above 200°C reduced hygroscopic behavior and swelling, while it increased dimensional stability (Tuong and Li, 2010; Surini et al., 2012). A similar result was found with *Eucalyptus camaldulensis* wood by Unsal et al. (2003). Heat treatment applied at different temperatures (120, 150 and 180°C) and duration (2, 6 and 10 h) caused significant decreases in the tangential and radial swelling percentages of the eucalyptus wood. The greatest changes were observed with the highest heat treatment (10 h at 180°C). In another study in which the effect of heat treatment on physical properties of Turkish hazel (*Corylus colurna*) was analyzed, it was found that, depending on temperature increase and duration, there was a statistically significant decrease in the percentage of tangential, radial and longitudinal swelling in the experimental samples compared to control samples (Korkut et al., 2008).

In a study in which heat treatment was applied to hornbeam wood and Uludağ fir wood between 170 and 210°C for 4 to 12 h, all the heat-treated samples revealed lower percentages of water absorption (WA) and swelling when compared to control samples. The WA and anti-swelling efficiency (ASE) values of Uludağ fir wood were found to be higher than those of hornbeam wood. At the end of the application at 210°C for 12 h, it was observed that the WA decrease in the Uludağ fir wood was 44.55%, while the WA decrease in the hornbeam wood was 42.51%. The differences in the percent of swelling were said to be similar to those of the WA values (Aydemir et al., 2011).

Worldwide, the largest forests of narrow-leafed *ash (NLA, Fraxinus angustifolia Vahl.), one of the important ash subspecies, are located in Turkey. After populus and alder, this is one of the native species which grows fastest* (Çiçek & Yılmaz, 2002). In planted stands of NLA in Turkey, the mean annual volume increment (MAI) can reach up to 23 m^3/ha; additionally, the current annual volume increment (CAI) can reach up to 33 m^3/ha for trees aged 15 to 20 years (Kapucu et al., 1999). NLA wood is classified as having moderate density. Moreover, in terms of tangential and radial shrinkage percentages, it is classified in the surplus trees group (As et al., 2016). Fast- growing tree species exhibit extensive juvenile wood growth with thin heartwood. As a result of rapid growth, the wood displays large annual rings and low density. This situation reduces the dimensional stability of the wood as well as its durability against biological hazards (Li, 2002). The ash trees used in this study are included in the slightly durable group, according to the natural durability classification of wood, with the natural durability persisting less than five years (Findlay, 1985).

This study examined the effect of heat treatment applied at different temperatures (120, 160, 190 and 210°C) and times (3, 6, 9 h) on the WA and water repellent effectiveness (WRE) values and the dimensional stability of ash wood grown in natural forests. Thus, the aim was to gather data on the effect of heat treatment on the working characteristics of natural ash wood and to enhance the low-dimensional stability of the ash wood.

MATERIALS AND METHODS

Materials

In the study, raw wood samples were obtained from floodplain forestlands belonging to Süleymaniye sub-district Directorate of Forestry and Hendek Directorate of Forestry. In accordance with the study, a stand including the same properties of habitat was specified. The research area is located on a plain bottomland where the Dinsiz and Mudurnu Streams flow and join with the Sakarya River. With the increasing precipitation in the fall, the forest first becomes a swamp. Later, the level of water reaches up to 1 or 1.5 m in the period between January and May (especially in spring when the snow melts) and the forest can be reached via a boat. The vegetation period ranges between 230 and 240 days from April through November. During the vegetation period, the monthly temperature is >10°C and the monthly precipitation is 56 mm. This region lies in the climate transition zone between the Marmara marine climate and the Black Sea climate.

Selection of Sample Trees

This study used NLA wood from the Adapazarı Province, where this species is most extensively found. Considering habitat properties such as direction, bend, diameter, height and sequence, four sample trees with similar mean diameter at breast height (DBH) and having no cracks or abnormal canopy development were cut down and removed from the area. The general properties of the sample trees were determined according to TS 4176 (1984) principles (Table 1).

Table 1. General properties of the ash (*Fraxinus angustifolia* Vahl.) trees

Tree No	Age (years)	Diameter (cm)	Height (m)	Nodes (number)	Branchless Stem (m)
1	40	33	28	15	17
2	32	28	23	9	10
3	38	31	25	9	11
4	32	27	24	10	12

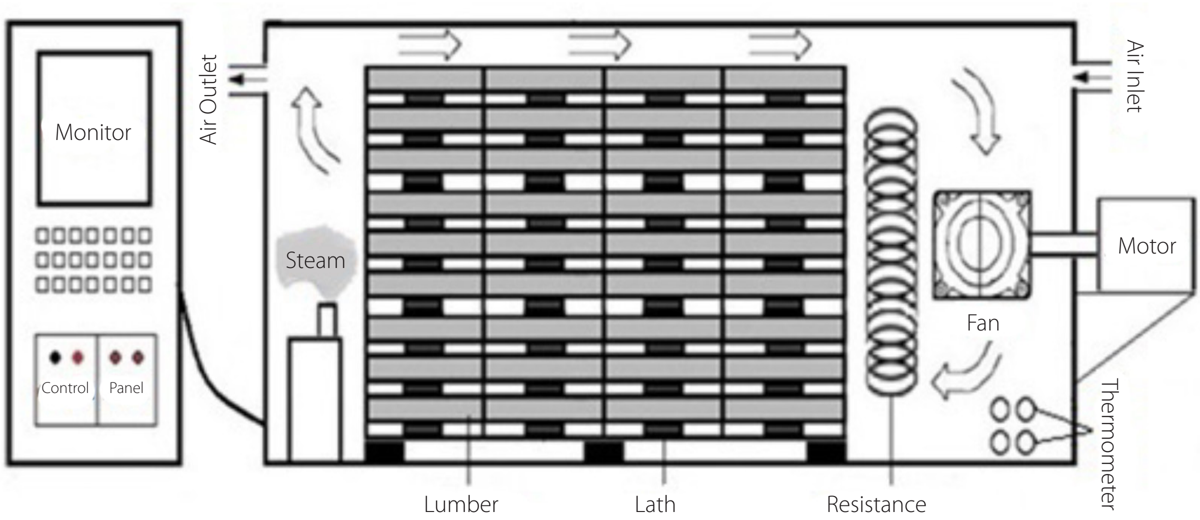

Figure 1. A schematic view of heat treatment kiln (Şahin 2014)

Preparing Test Samples

For the test samples used in the study, suitable healthy sections between 2 and 4 m above the ground root were utilized. The felled trees were cut into logs 1 to 1.5 m in length and stacked In the Adapazarı-Hendek Forest Sub-District Directorate lumber yard. Later, the logs were stripped of bark and 6-cm-wide boards were sawn, with the heartwood positioned in the center. The sawing procedure was carried out in accordance with the TS 2470 (1976) principles. The boards were tallied again and stacked in wood dunnage where they were stored in a sheltered area for air seasoning. To minimize the differences in the samples caused by the wood structure, the experimental and control samples were prepared having the same consecutive annual rings in the longitudinal axis of the boards. Experiment numbers for each trial were written on the experimental samples with an acetate pen.

Methods

Heat Treatment

The experimental samples used in the study were prepared from flawless specimens in standard specified dimensions of 30 × 30 × 15 mm (T × R × L). Before heat treatment, the samples were kept in a climatic chamber at 20±2°C and 65±5% relative humidity for 4 weeks to ensure a moisture balance of 11-14%. The samples were subjected to heat treatment in a total of 12 variations including four different temperatures and three different time durations. The heat treatment procedure was carried out in a heat treating furnace with the capacity of 1 m^3, ±1°C equipped with a computerized precise temperature control system (Figure 1). The heat treatment parameters could be controlled automatically or manually on the control panel of the heat treating furnace.

The samples were heat-treated in a water vapor atmosphere at temperatures of 120, 160, 190 and 210°C over a period of 3, 6 and 9 h. During heat treatment, both the samples and air temperature were measured. In the first phase, the temperature of the furnace was raised to about 100°C. In the procedure known as high-temperature drying, vapor is released into the furnace to avoid surface checking or internal splitting caused by the shock of drying. At the same time, the wood material inside the furnace is prevented from burning. During this phase, the moisture of the wood was lowered to nearly zero. When the internal temperature was equivalent to the ambient temperature, the heat of the furnace was cautiously increased to the target heat treatment temperatures. The procedure continued at these temperatures throughout the specified time periods.

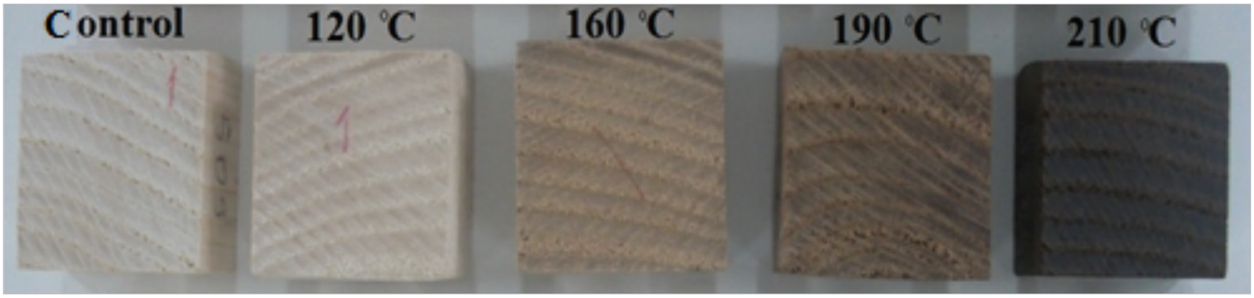

Figure 2. The test and control samples used in WA experiment (Şahin 2014)

The last phase was the cooling and conditioning. During this phase, the aim was to prevent the wood, which had reached a high temperature in the furnace, from cracking from the effects of the colder outside atmosphere. The internal temperature was lowered to 80 or 90°C with the help of a water-spray system and the samples were conditioned under the control of the water vapor atmosphere. At the end of this stage, the moisture content of the wood ranged between 4% and 7%, depending on the temperature of the heat treatment. The test samples remained inside the furnace for an average of 27 h in all combinations applied (including the heating, pre-dry and conditioning procedures), excluding the heat treatment period (Şahin, 2014). After heat treatment, the test samples were placed in the climatic chamber again in order to reach equilibrium moisture content (Figure 2). The experiments carried out on the heat-treated samples and the sample numbers used for each experiment were determined according to TSI CEN/TS 15679 (2011) standards.

Water Absorption and Water Repellent Effectiveness
The experimental samples used to identify WA and WRE values were prepared in dimensions of 30 × 30 × 15 mm (Figure 2). In the experiments, 20 test samples were used separately for control or experimental samples.

The heat-treated experimental samples and the control samples having the same annual rings as the experimental samples were dried to constant weight at 103±2°C and their dimensions and dry condition weights were established as 0.01 mm and 0.01 g, respectively. The control and experimental samples were then soaked in water at 20±1°C. At the end of 2, 4, 8, 24, 48 h and 1 and 2 week periods, the amount of water absorbed by the control and test samples was measured. For this procedure, at the end of each soaking period, the samples were removed from the water and wiped with a napkin. They were weighed on a scale and the amount of water absorbed (A_{bs}) was recorded. Using the dry weight at the beginning, the WA value (%) of each experimental sample (P_{ao}) or control sample (A_o) was calculated separately for each period, according to the formula below (Yıldız, 2002).

$$WA = \frac{A_{bs} - P_{a0}(or\ A_0)}{P_{a0}(or\ A_0)} \times 100$$

The WRE value (%), defined as the decline that occurs in the WA of heat-treated wood samples compared to untreated wood, was calculated separately for each period and for each experimental and control sample according to the formula below.

$$WRE = \frac{(WA_c - WA_t)}{WA_c} \times 100$$

In the equation,
WRE: Water repellent effectiveness,
WA_c: WA (%) of the control sample at the end of a specified period,
WA_t: WA (%) of the experimental sample at the end of a specified period.

Swelling and Dimensional Stability
The samples used in the WA and WRE tests were utilized in the tests for the amount of swelling and dimensional stabilization. In the relevant tests, the dimensions of the test and control samples in the tangential direction under dry conditions were determined by calipers with 0.01 mm sensitivity. The samples were soaked in water until their dimensions remained constant and then were measured again from the same points. After the measurements were made by following the general principles in TS 4084 (1983), the percentage of tangential swelling (α_{tg}) was calculated according to the formula below.

$$\alpha_{tg} = \frac{(T_2 - T_1)}{T_1} \times 100$$

In the equation;
T1: The dimension of samples in the tangential direction under dry conditions (mm),
T2: The dimension of samples in the tangential direction after soaking in water for 2 weeks (mm).

The ASE values (%), which describe the decrease in the amount of swelling of the test samples compared to the control samples and accordingly, the dimensional stabilization gained through heat treatment, were calculated using the formula below (Yıldız, 2002).

$$ASE = \frac{(c\alpha_{tg} - t\alpha_{tg})}{c\alpha_{tg}} \times 100$$

Table 2. Mean WA of heat treated ash wood test and control samples at different temperatures and times (%)

Temperature (°C)	Time (h)	Immersion Time								p
		2 h	4 h	8 h	24 h	48 h	72 h	1 wk	2 wk	
120	K	21.19b*	27.25d	33.91f	48.41g	58.49h	64.44j	72.49m	78.99o	0.000
		(2.35)**	(2.63)	(2.73)	(4.22)	(4.87)	(4.9)	(4.95)	(4.79)	
	3	19.09a	24.97c	31.21e	48.20g	61.27i	65.50jk	70.69l	76.60n	
		(0.19)	(0.3)	(0.89)	(2.39)	(2.12)	(3.63)	(2.81)	(2.45)	
	6	18.65a	24.26c	31.48e	47.11g	60.97i	66.30k	72.11lm	78.34no	
		(0.48)	(0.48)	(1.29)	(2.17)	(1.95)	(2.29)	(2.24)	(1.49)	
	9	18.28a	24.25c	30.78e	46.96g	59.98hi	64.93jk	70.64l	77.20n	
		(0.51)	(0.34)	(1.09)	(2.68)	(2.7)	(2.51)	(3.2)	(1.31)	
160	K	21.19c	27.25f	33.91i	48.41l	58.49o	64.4pr	72.49u	78.99y	0.000
		(2.35)	(2.63)	(2.73)	(4.22)	(4.87)	(4.9)	(4.95)	(4.79)	
	3	19.33b	25.10e	30.01gh	41.79j	50.73m	57.69o	67.06s	73.63u	
		(0.43)	(0.78)	(0.84)	(1.00)	(1.21)	(1.73)	(1.84)	(1.86)	
	6	17.8ab	23.6de	30.94h	46.50k	58.34o	63.40p	69.92t	77.16v	
		(0.71)	(0.63)	(1.07)	(2.78)	(2.6)	(2.73)	(3.15)	(3.94)	
	9	17.00a	22.43cd	28.6fg	42.11j	52.72n	58.42o	65.97rs	73.48u	
		(0.9)	(1.02)	(1.37)	(1.35)	(1.8)	(3.14)	(2.35)	(3.05)	
190	K	21.2bc	27.25e	33.91g	48.41j	58.49o	64.44p	72.49s	78.99u	0.000
		(2.35)	(2.63)	(2.73)	(4.22)	(4.87)	(4.9)	(4.95)	(4.79)	
	3	16.33a	22.58c	29.31f	42.33i	51.72l	57.32no	66.57r	75.18t	
		(0.67)	(1.03)	(1.41)	(1.51)	(1.87)	(2.03)	(2.16)	(2.74)	
	6	16.51a	20.36b	27.33e	41.21i	50.23kl	55.94mn	65.62pr	74.69t	
		(0.8)	(0.95)	(0.67)	(2.17)	(2.06)	(2.13)	(2.45)	(3.49)	
	9	16.04a	20.25b	24.56d	39.54h	48.77jk	54.49m	64.52p	73.52st	
		(0.66)	(1.16)	(0.88)	(2.04)	(2.81)	(2.84)	(2.98)	(1.53)	
210	K	21.19c	27.25f	33.91g	48.41l	58.49o	64.4pr	72.49s	78.99u	0.000
		(2.35)	(2.63)	(2.73)	(4.22)	(4.87)	(4.9)	(4.95)	(4.79)	
	3	16.35a	20.37bc	25.28e	39.80j	49.41l	54.94m	63.28p	71.47s	
		(0.84)	(0.88)	(0.77)	(0.95)	(1.15)	(1.6)	(1.45)	(2.41)	
	6	15.73a	19.54b	23.46d	38.17i	49.36l	56.47n	65.78r	74.35t	
		(0.79)	(0.93)	(0.97)	(1.15)	(1.51)	(1.4)	(2.2)	(2.1)	
	9	14.99a	19.01b	22.89d	35.91h	46.57k	54.67m	63.24p	71.71s	
		(0.93)	(1.15)	(1.3)	(1.29)	(1.69)	(1.17)	(1.43)	(1.97)	

*Same letters appearing in a column indicate no statistical differences between the means ($p<0.05$), ** Standard deviation values are given in parentheses, C: Control sample, wk: week, h: hour, p: Significance level

In the equation;
ASE: Anti-swell effectiveness,
cαtg: The percentage (%) of swelling of control samples in the tangential direction,
tαtg: The percentage (%) of swelling of experimental samples in the tangential direction.

ATR-FTIR Analysis

Ash wood powder obtained from three stands and passed through an 80-mesh sieve was used for the Fourier transform infrared spectroscopy (FTIR) analysis. According to the attenuated total reflection (ATR) method, absorption peaks were directly obtained without applying any pre-treatment. The FTIR analyses

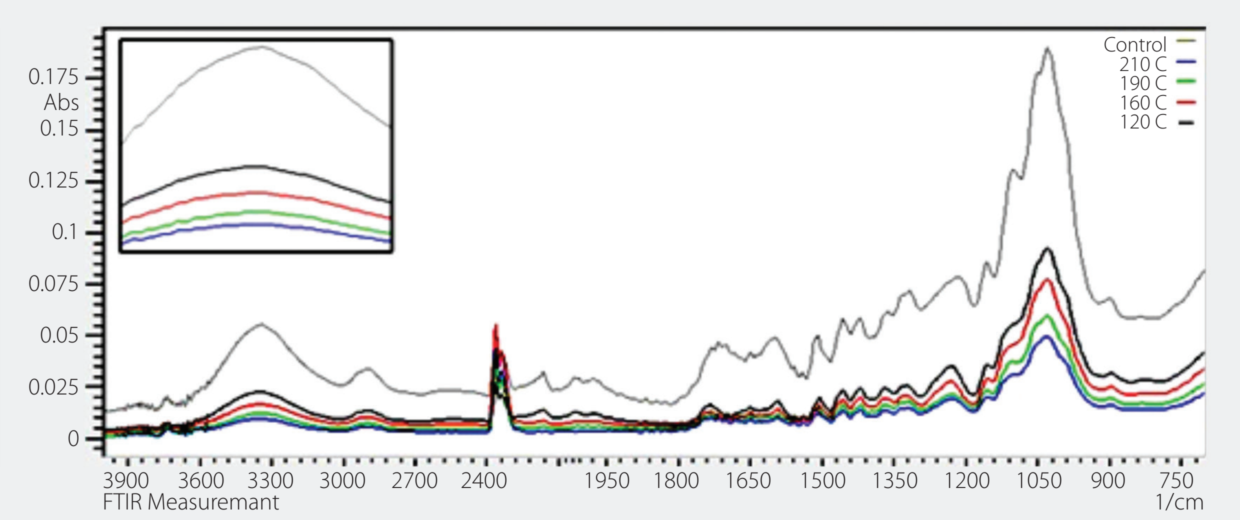

Figure 3. ATR-FTIR spectra of heat-treated ash wood for 3 h at different temperatures and control samples

were conducted via 4000 and 700 cm^{-1} wavelengths and 4 cm^{-1} solubility using the Shimadzu IR Prestige-21 spectrophotometer. The analyses were carried out by completing 20 scans for each sample.

Statistical Analysis

The data were analyzed using the statistical package program SPSS 19 software. In all comparisons, the level of significance was taken as 0.05 (95%). Simple analysis of variance (ANOVA) was used to determine any statistically significant differences between the experimental groups, with four different temperatures and three different times applied during heat treatment, and the control groups. The means obtained via the ANOVA were compared using Duncan's new multiple range test separately for each variation.

RESULTS AND DISCUSSION

Effect of Heat Treatment on Water Absorption (WA)

The means of the WA and statistical results for the different water immersion times of the NLA test samples subjected to heat treatment at different temperatures (120, 160, 190 and 210°C) for different times (3, 6 and 9h) and of the control samples are presented in Table 2. According to the results obtained, in each variation applied, the increases in WA values of the test and control samples were dependent on the increase of the immersion time. The results of the ANOVA indicated that the differences between the mean WA values of each variation depending on the immersion time were statistically significant ($p<0.05$, Table 2).

In the test and control samples of NLA, the mean values of WA increased depending on the immersion time. At the end of the 2, 4 and 8h immersion times, the WA values of all test samples to which heat treatment was applied were found to be different from the control samples ($p<0.05$). Depending on the increase of heat treatment temperature and time period, the WA values decreased. For example, the WA value of the control sample was 21.19% at the 2h immersion time while the WA value was decreased to 14.9% for test samples (210°C and 9h) at the same immersion time. The WA values of the test and control samples especially regarding the heat treatment at 190 and 210°C were found to be statistically different from one another for each immersion time ($p<0.05$).

In some studies in the literature, it has been reported that, depending on commercial heat treatment, the WA values of eucalyptus (Cademartori, 2014), acacia (Van Chu, 2013), juniper (Kasemsiri, 2012), black pine (Dündar et al., 2012) and fraxinus ash (Korkut et al., 2012) woods decreased. In another research, at the end of thermal treatment applied at 180°C over 2, 4, 6, 8, and 12h, the water adsorption of Castanea sativa wood samples decreased with the rise in the duration of heat treatment (Gündüz & Aydemir, 2008).

In their research, Kocaefe et al. (2008) determined the physical, mechanical and fungal properties of heat-treated pine and populus wood. They stated that an extraordinary decrease occurred in the WA values of wood samples soaked in water for 24 h. The decrease in the pine WA was 38%, while this value in the populus wood was 14%.

In a study which examined the effect of heat treatment at different temperatures on the WA properties of heartwood and sapwood of pine and spruce, it was reported that the heartwood of both wood types absorbed less water than the sapwood. The heat treatment visibly decreased the WA values of pine and spruce heartwood. The WA values of the pine sapwood decreased at 230°C (Metsä-Kortelainen et al., 2006).

In general, for all immersion times, the WA values of the test samples treated at different temperatures decreased to some extent when compared to the WA values of the control samples (Table 2). The modification in the chemical structure of

Table 3. Mean WA of heat treated ash wood test and control samples at different temperatures and times (%)

Temperature (°C)	Time (h)	Immersion Time								p
		2 h	4 h	8 h	24 h	48 h	72 h	1 wk	2 wk	
120	3	9.94[bcd]*	8.36[de]	7.96[de]	0.43[ghi]	-4.75[k]	-1.65[ij]	2.48[fg]	3.02[f]	0.000
		(0.89)**	(1.11)	(2.62)	(4.93)	(3.63)	(5.64)	(3.87)	(3.1)	
	6	11.99[ab]	10.97[bc]	7.17[e]	2.67[fg]	-4.24[k]	-2.89[jk]	0.52[fghi]	0.81[fgh]	
		(2.27)	(1.78)	(3.81)	(4.48)	(3.34)	(3.56)	(3.09)	(1.89)	
	9	13.72[a]	11.01[bc]	9.24[cde]	2.99[f]	-2.55[jk]	-0.77[hij]	2.55[fg]	2.27[fg]	
		(2.39)	(1.23)	(3.22)	(5.53)	(4.61)	(3.9)	(4.41)	(1.66)	
160	3	8.78[fgh]	7.88[gh]	11.52[de]	13.67[cd]	13.26[d]	10.47[ef]	7.48[gh]	6.78[h]	0.000
		(2.01)	(2.85)	(2.48)	(2.06)	(2.07)	(2.68)	(2.54)	(2.36)	
	6	15.84[bc]	13.50[cd]	8.76[fgh]	3.94[i]	0.26[j]	1.62[ij]	3.54[i]	2.31[ij]	
		(3.36)	(2.31)	(3.14)	(5.74)	(4.45)	(4.24)	(4.35)	(4.99)	
	9	19.78[a]	17.70[ab]	15.72[bc]	13.01[d]	9.86[efg]	9.35[efgh]	9.00[fgh]	6.97[h]	
		(4.26)	(3.75)	(4.03)	(2.78)	(3.08)	(4.87)	(3.24)	(3.87)	
190	3	22.95[cd]	17.13[efg]	13.57[hij]	12.56[ijk]	11.58[jkl]	11.06[kl]	8.17[mn]	4.82[o]	0.000
		(3.18)	(3.77)	(4.16)	(3.12)	(3.19)	(3.16)	(2.98)	(3.47)	
	6	22.09[d]	25.26[abc]	19.41[e]	14.88[ghi]	14.13[hi]	13.19[hijk]	9.48[lm]	5.44[o]	
		(3.75)	(3.47)	(1.98)	(4.48)	(83.53)	(3.3)	(3.38)	(4.42)	
	9	24.33[bcd]	25.67[ab]	27.57[a]	18.33[ef]	16.62[fg]	15.44[gh]	10.99[kl]	6.92[no]	
		(3.13)	(4.25)	(2.58)	(4.21)	(4.81)	(4.4)	(4.11)	(1.93)	
210	3	22.86[e]	25.25[d]	25.44[d]	17.78[g]	15.53[h]	14.74[h]	12.71[i]	9.52[j]	0.000
		(3.98)	(3.22)	(2.26)	(1.96)	(1.97)	(2.49)	(2)	(3.06)	
	6	25.75[d]	28.31[c]	30.81[ab]	21.15[ef]	15.62[h]	12.37[i]	9.26[j]	5.87[k]	
		(3.73)	(3.41)	(2.87)	(2.38)	(2.59)	(2.17)	(3.04)	(2.65)	
	9	29.25[bc]	30.22[bc]	32.50[a]	25.82[d]	20.38[f]	15.17[h]	12.75[i]	9.21[j]	
		(4.37)	(4.22)	(3.84)	(2.68)	(2.9)	(1.81)	(1.97)	(2.5)	

*Same letters appearing in a column indicate no statistical differences between the means ($p<0.05$), ** Standard deviation values are given in parentheses, wk: week, h: hour, p: Significance level.

the wood by heat treatment applied at above 200°C even in a shielding gas environment influenced all properties of the wood. When wood absorbs moisture in the environment, water molecules try to enter through the wood polymers (hemicellulose and amorphous cellulose). The OH groups are loosened and crosslinks of wood fibers are formed as a result of heat treatment, which significantly lessens the capacity of water to enter the wood (Homan et al., 2000; Tuong and Li, 2010). This fact indicates the main reason that the test samples exhibited less WA than the control samples.

The ash wood samples heat-treated at different temperatures are characterized via ATR and FTIR spectral analysis peaks in Figure 3. The FTIR analyses were applied to all temperature variations, and the 3-hour differences for each temperature are marked in the figure below.

The ash wood samples showed similar spectra results after the heat treatment. The fact that most of the hemicelluloses were removed in the heat-treated test samples was understood from the decrease in the volume of the absorption peaks in the FTIR spectra at 1740 and 1590 cm^{-1} emerging from the C=O and C-O groups which contain hemicellulose (xylan) (Figure 3). In addition, the fact that the free hydroxyl groups (–OH) which cause significant decreases in the WA of ash wood had actively loosened can be explained by the decrease in the absorbance values of the peaks observed at the 3350 cm^{-1} frequency, with the OH stretching vibration depending on rising temperature. Similar results were found in research carried out by Miklecic et al. (2011).

Effect of Heat Treatment on Water Repellent Effectiveness (WRE)
The WRE values indicated the decrease in the WA of the heat-treated test samples compared to the control samples.

Table 4. Mean ASE values of heat treated ash wood at different temperatures and times (%)

Temperature (°C)	Time (hour)	ASE (%)	HG	S	Min	Max	p
120	3	3.62	a*	1.00	1.56	5.58	
	6	5.28	b	0.76	3.56	6.25	
	9	7.66	c	0.85	6.31	9.27	
160	3	15.66	d	1.03	13.62	17.86	
	6	17.14	e	0.96	15.38	18.88	
	9	21.06	f	1.11	19.54	23.82	0.000
190	3	40.17	g	1.17	37.62	42.39	
	6	46.50	h	1.51	43.20	48.52	
	9	49.44	i	2.08	46.22	54.43	
210	3	51.08	j	1.29	48.35	53.69	
	6	54.29	k	2.19	48.27	58.61	
	9	58.36	l	1.68	55.08	62.06	

*Same letters appearing in a column indicate no statistical differences between the means ($p<0.05$), ASE: anti-swell effectiveness, HG: Homogeneous group, S: Standard deviation, Min: Minimum value, Max: Maximum value, p: Significance level.

The arithmetic means, standard deviation, statistical homogeneity groups and statistical data related to WRE values of the test samples immersed in distilled water for various periods after heat-treatment are presented in Table 3.

In general, the highest WRE values were detected in the 9-hour heat treatment at all temperatures and periods of soaking in water procedures. According to Table 3, compared to the control samples, the WRE values in the ash wood samples heat-treated at 120°C were related to short-term (2, 4 and 8 h) immersion time increases. At the end of the 48-hour immersion time, the WRE values began to decline rapidly and decreased below those of the control samples (e.g. -2.55%). The WRE values at 48-hour and 72-hour immersion times became negative (in which case the heat-treated test samples absorbed more water than the control samples) for all heat treatment periods. After treatment via some water-repellent enabling processes, the test wood samples absorbed less water than the control samples. However, when the water immersion time was increased, the amount of water that the test wood absorbed approached that of the control samples (Yıldız, 2002).

The WRE values obtained from the heat treatment at 190°C for 3 and 6 h decreased depending on the increase in the periods of soaking in water. The WRE values increased for the 9-hour heat treatment up to the completion of the 8-hour immersion time, after which they decreased (Table 3). According to the results, the highest WRE value among heat-treatment periods was obtained at the 8-hour periods of soaking in water with the 9-hour treatment (27.6%) and this value was found to be statistically different from all other variations ($p<0.05$).

The effect of the heat treatment applied at various temperatures and times on the dimensional stability of acacia wood was studied by Vah Chu (2013), who stated that improvements of 15-46% in dimensional stability and 8-18% in water-repellent effectiveness were observed at the end of heat treatment carried out in air.

For each temperature application, the highest WRE values were obtained at the lowest periods of soaking in water (2, 4 and 8 h) procedures. A decrease in WRE values was observed, especially in the period of 24 h and after, depending on the increase of the immersion time. Dündar et al. (2012) applied heat treatment at 180 and 210°C for 3 h on black pine timber which included compression and opposite wood by using the commercial Thermowood method. Consequently, while the maximum WRE values were obtained in the short-term immersion time periods for all processes, the heat-treated wood lost that positive effect with the increase of the application period. Once again, the highest WRE values were attained from the 9-hour heat treatment at all immersion time periods. In addition, when the temperature of heat treatment was increased, an overall increase in the WRE values was observed. The he lowest WRE values were seen at 120°C, while the highest values were determined at 210°C with the 9-hour treatment. In one study, after an 8-hour periods of soaking in water, the WRE values of beech heat-treated at 200°C over 6 and 10 h were respectively 36% and 42.5% (Yıldız, 2002). Heat-treatment was applied on beech and spruce wood with various vegetable oils by Tomak et al. (2011) and in all applications, the WA% decreased compared to control samples, and increases in WRE values were determined.

Effect of Heat Treatment on Anti-Swelling Effectiveness (ASE)

The decrease in the swelling amount of the ash wood test samples taken from growth forests and heat-treated at various temperatures and times was compared to that of the control samples. The ASE values describing the dimensional stability gained as a result of heat treatment along with other statistical data are shown in Table 4. According to the ANOVA results, it was concluded that the difference between the mean ASE values of each variation was statistically significant ($p<0.05$). For this reason, in order to reveal which of the variations was the source of the significant difference, Duncan's new MRT was conducted. According to the results, significant differences were found in the ASE values at all heat treatment temperatures and times (Table 4).

Increases in the ASE values were determined depending on increasing of the temperature and time period. Especially in the application at 190°C for 3 h, the ASE values rose rapidly to over 40%. The highest ASE values were obtained when the heat treatment was applied at the most severe variation. There have been a number of studies examining the fact that heat treatment increases ASE values in a directly proportional way to the increasing temperature and time (Esteves et al., 2007; Tuong and Li, 2010; Cao et al., 2012). In another study, the dimensional stability values of oriental beech wood heat-treated under atmospheric pressure between 130 and 200°C for 2, 6 and 10 h increased in direct proportion to the rise in the temperature and time; this value reached 50% at 200°C (Yıldız, 2002).

Dimensional stability values occurring with numerous heat treatments of between 100 and 240°C lasting 1 to 48 h on fir, spruce, beech, eucalyptus, oak, acacia and rubber tree (Ficus elastic) woods were studied. In general, it was reported that dimensional stability of between 40% and 90% was acquired with the increasing temperature and time of the heat treatments and also depending on the method (Edvardsen and Sandland, 1999; Yıldız, 2002; Srinivas, 2012; Cao et al., 2012; Van Chu, 2013; Cademartori, 2014).

While the ASE value was 49.4% at 190°C with the 9-hour application of heat treatment, this value reached 58.4% at the application of 210°C for 9 h. The lowest ASE value was achieved when the heat treatment temperature and period were at the lowest (3.62%).

Some physical and mechanical properties of hornbeam wood heat-treated at three different temperatures (130, 160 and 190°C) and times (3, 6 and 9 h) were investigated, and as a result of the heat treatment, the decrease in the ASE values were higher in the tangential direction of the wood than in the other (radial and longitudinal) directions. The highest ASE ratio (40.58%) was obtained at 190°C and a 9-hour application in the tangential direction (Ghalehno & Nazerian, 2011). In a study carried out with eucalyptus wood by Calonego et al. (2012), it was found that the thermal modification caused a decrease of 53.3% in the ratio of volumetric swelling.

Another study evaluated the effect of heat treatment on the physical, mechanical and color properties of eucalyptus wood. According to the results, there were significant decreases in the amount of tangential and radial swelling of the eucalyptus wood depending on the increases in heat treatment temperature and period, with the highest ratio of decrease (21.5%) being observed with the most severe heat treatment (180°C for 10 h) in the tangential direction (Ünsal et al., 2003).

In the literature, several reasons are stated for the fact that dimensional stability is enhanced by heat treatment. Tjeerdsma et al. (1998) reported that the loss of methyl radicals belonging to some syringyl and guaiacyl units of lignin may be a possible cause for the enhancement of dimensional stability. In this case, there is an increase in the ratio of phenolic groups and units in free ortho positions. As a result of these chemical modifications, lignin generates some cross-links and passes more reactive positions, thus increasing dimensional stability. In addition, the elasticity of cellulose molecules is reduced by the increase in crosslinking. When water is absorbed, less swelling occurs in these molecules. Therefore, the amount of equilibrium moisture of the wood material is reduced and its dimensional stability increased.

Treatment at high temperature modifies the structure of wood and reduces the proportion of hemicellulose (Kantay et al., 1995). In addition, as the amount of hydroxyl groups decreases, the cell wall of the wood absorbs less water. For this reason, when heat treatment is applied to wood material, its dimensional stability is enhanced. Because hemicelluloses are highly hygroscopic, the decrease in the content of hemicellulose during heat treatment increases the dimensional stability of treated wood compared to control samples (Tjeerdsma et al., 1998; Yıldız et al., 2006; Tuong and Li, 2010; Priadi and Hızıroğlu, 2013; Akkılıç et al., 2014).

CONCLUSION

In this research, the effect of heat treatment in a water vapor atmosphere on the dimensional stability of ash (Fraxinus angustifolia Vahl.) The wood was examined and statistically significant differences were determined in the WA, WRE and ASE values between the test and control samples. The WA of the ash wood control and test samples increased depending on increasing immersion times. Generally, the WA of the test samples in different temperature groups decreased slightly for all immersion time when compared to the control samples (Table 2). However, longer immersion times reduced the effect of heat treatment on the WA. In this study, increases of WRE values in certain amounts took place in proportion to the increase in the temperature and period of heat treatment (Table 3). As a result, in order to increase the WRE values of ash wood, the temperature and time of heat treatment need to be at the highest level.

The temperature and time of the heat treatment applied affected the ASE values (dimensional stability) linearly. That is to say, as the temperature and time of the heat treatment increased, the dimensional stability also gained increases. The best results were obtained with the long heat treatment (9 h) at 210 °C (58.36%). According to these evaluations, in order to enhance the working property of ash wood, in a way similar to increasing WRE values, applying heat treatment at the highest temperature and duration will yield the best result. Therefore, heat-treated ash wood could be recommended for areas of use where dimensional stability is important (e.g., doors, windows, floors, bathrooms, saunas, decks and siding).

Like ash wood, other rapidly-growing tree species, especially those with low dimensional stability, could also be given added value via heat treatment applications and as a result could become competitive with the tropical tree species commonly used for many purposes nowadays.

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Original Article

Determination of temporal changes in land uses in Hasanlar Dam basin

Hasanlar baraj havzasında arazi kullanımındaki zamansal değişimlerin belirlenmesi

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ABSTRACT

The impact of human activities on nature is increasing day by day along with changing patterns of land use. These changes also influence the level of the expected function of natural ecosystems. Therefore, for the purposes of meeting the needs of a growing population for ecosystem services at optimal levels, it is important to understand and control the factors that affect land use and to control the changes in land use according to the objectives. The aims of this study were to determine land-use patterns in Hasanlar Dam basin per period, analyze the temporal changes in land use according to area, and determine the reasons for the changes in the basin by digitizing the maps of the basin area belonging to the period between 1986 and 2010. Forest land-use patterns were categorized into the following six groups: forest, (deciduous, coniferous, mixed, and degraded), forest gaps, hazelnut, agriculture, pasture, and other areas. The forest area that was 64,843 ha in 1986 had declined to 62,709 ha in 2010. Hazelnut areas covering an area of 3,636 ha in 1986 were represented as agricultural areas in the 2010 stand maps. The agricultural areas that were 8,925 ha in 1986 increased to 15,420 ha in 2010. The pasture areas comprising 267 ha in 1986 decreased to 19 ha in 2010. Other areas decreased from 1,302 ha to 825 ha between 1986 and 2010. Through the Melen project, water is being transported to İstanbul from Hasanlar Dam. Therefore, since changes in the land-use pattern in the Hasanlar Dam basin may affect both water efficiency hydrologically and the quality of water, it is necessary to monitor the changes in forest, agriculture, pasture, forest soil, and other areas and also the changes in the demographic structure. In addition, it must be ensured that these changes cause the minimum impact on water yield and quality.

Keywords: Land-use changes, GIS, Hasanlar dam basin, temporal changes

ÖZ

İnsanların doğa üzerindeki etkileri gün geçtikçe artmakta ve arazi kullanım biçimleri değişmektedir. Bu değişimler, doğal ekosistemlerden beklenen fonksiyonların düzeyini de etkilemektedir. Bu nedenle artan nüfusun ekosistem hizmetlerine yönelik gereksinimlerinin optimal düzeyde karşılanabilmesi için arazi kullanımında etkili faktörlerin anlaşılması ve değişimlerin amaçlar doğrultusunda kontrol edilmesi önemlidir. Bu çalışmada, Hasanlar baraj havzasının 1986-2010 yıllarına ait meşcere haritaları, bilgisayar ortamında sayısallaştırılarak, dönemler itibariyle arazi kullanım biçimleri belirlenmeye, arazi kullanımındaki zamansal değişimler alansal olarak hesaplanmaya ve değişimin sebepleri belirlenmeye çalışılmıştır. Arazi kullanım biçimleri orman (yapraklı, ibreli, karışık, bozuk), orman toprağı, fındıklık, ziraat, mera ve diğer alanlar olmak üzere 6 gruba ayrılmıştır. Orman alanları 1986'da 64 843 ha iken 2010 yılında 62 709 ha'a gerilemiştir. Fındık alanları 1986'da 3 636 ha'lık bir alana sahipken 2010 yılı meşcere haritalarında ziraat alanları içerisinde gösterilmiştir ve 1986 yılında 8925 ha olan ziraat alanları 2010 yılında 15 420 ha'a yükselmiştir. Mera alanları 1986'da 267 ha iken 2010'da 19 ha'a gerilemiştir. Diğer alanlar 1986-2010 yılları arasında 1302 ha'dan 2010'da 825 ha'a gerilemiştir. Melen projesi ile Hasanlar barajından İstanbul'a su taşınmaktadır. Dolayısı ile Hasanlar barajı havzasındaki arazi kullanımının değişmesi hidrolojik olarak hem su verimini hem de su kalitesini etkileyebileceğinden orman, ziraat, mera, orman toprağı, diğer alanlar ve demografik yapıdaki değişimlerin izlenmesi, su verimi ve kalitesinin bu değişimlerden en az şekilde etkilenmesinin sağlanması gerekmektedir.

Anahtar Kelimeler: Arazi kullanım değişimi, CBS, Hasanlar baraj havzası, zamansal değişim

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INTRODUCTION

There has been a constant change in the spatial and structural characteristics of forests and forest stands, which form the forests, due to natural events and also technical interventions. Structural changes in turn lead to various land-use changes, which may end up with deforestation. Local changes occurring at the stand level can cause problems in the functioning of the entire forest ecosystems and prevent the realization of the expected operations. Throughout history, people have fulfilled several of their requirements from forests. Issues such as the sustainability of the forest were not a concern when the population density was low compared to that present today. However, due to the growing pressure on forest resources, issues such as ensuring the continuity of these sources has begun to gain importance. In this context, several initiatives and applications are available at both national and international levels for ensuring the sustainability of forest resources. In the United Nations Sustainable Forest Management Declaration (1992), emphasis was made on the necessity of sustainable use of forest resources on a global level (OGM, 2013).

The improper use of land and natural resources can cause several environmental problems such as floods and landslides, which are caused by factors such as soil compaction and deforestation. These problems also occur in the form of destruction of natural habitats as a consequence of climate change, loss of biodiversity, and pollution of water, air, and soil (European Environment Agency, 2010). In a world where natural resources are limited but the human need is unlimited, to ensure sustainable use, temporal changes in land use should be determined and lands should be used according to the land-use plans prepared by experts (Özçağlar et al. 2006). The geographic information system (GIS), in which analysis and examination are based on computational foundation, can be used in the studies conducted to achieve healthy results successfully and in a short time. In this context, the analysis and examination of the relationship between natural resources and existing land use is of paramount importance for future physical–civic planning approaches (Gülersoy, 2014).

There is extensive research addressing the land-use changes at both local and global levels. It has been estimated that for maintaining the existing land-use pattern in the European Union countries, agricultural land would be reduced gradually until the year 2080, which would also not meet the needs of the growing population (Rounsevell et al. 2005). Based on studies that have examined the effects of land use on soil and water resources, it has been observed that traditional land use has been abandoned and new methods of land use have resulted in land degradation and loss of biodiversity (Wu and Tiessen, 2002). In some of the recent studies conducted in Turkey, land-use changes were examined by Gülersoy (2013, 2014) in Manisa and Çorum Central Districts and by Somuncu et al. (2010) in the plateaus of Gümüşhane Province using various remote sensing methods. Özşahin and Atasoy (2014) evaluated land-use changes and soil characteristics of the lower parts of the Asi River. Erol (2007) addressed land use in Turkey through the basin approach. Kadıoğulları and Karahalil (2013) analyzed the temporal and spatial variations of the quantity of carbon in Köprülü Kanyon National Park. Değermenci and Zengin (2016) evaluated the spatial and temporal variations of the Daday planning unit along with carbon stock status and demonstrated the spatial and temporal variations in carbon accumulation. Studies conducted in Turkey have dealt with land-use changes in association with population, soil, erosion, water efficiency, and carbon variations. Forest cover in Turkey has increased steadily in terms of area in the last 30–40 years (OGM, 2015). However, this must not be considered as a uniform increase in every part of Turkey. The form of land-use changes between regions and countries and the land-use patterns vary in different regions even within the same country. Understanding the layout of land-use changes, the causes, and the possible consequences will help in identifying solutions in advance to the various problems that may arise in the future and will also help in improving the overall strategy (Bussink and Hijmans, 2000). In this context, knowledge of the related factors that affect land-use changes would provide invaluable information in terms of land-use planning and sustainable management of resources.

Therefore, the aim of this study was to determine the changes in land-use patterns and their causes in the Hasanlar Dam basin located on the Melen River within the boundaries of Bolu Regional Directorate of Forestry. For this purpose, changes in land-use patterns that have occurred between 1986 and 2010 in the dam basin, which consists of 11 forest chiefdoms (FCs), were spatially evaluated.

MATERIALS AND METHODS

General Characteristics of the Study Area

The study area consists of the Hasanlar Dam basin located in Düzce Province; the primary settlement in this area is the Yığılca town. In addition, within the study area, there are 50 villages that are connected to Yığılca, Kaynaşlı, and Düzce Province. The size of the study area is 78,973 ha, and it is located at 40° 47′06″ to 41° 02′02″ north latitude and 31° 24′03″ to 31° 40′45″ east longitude. The average elevation above the sea level is 937 m (Figure 1).

The agricultural areas of Yığılca, which has a rough and sloppy terrain, are inadequate generally covered with forest areas (Anonymous, 2014). The majority of forests are composed of pure and mixed stands, which include coniferous tree species such as black pine (*Pinus nigra*), Scotch pine (*P. sylvestris*), and fir (*Abies nordmanniana* subsp. *bornmuelleriana*). In addition, coniferous species usually blend with oriental beech (*Fagus orientalis*) and oak species (*Quercus* sp.). Deciduous species, beech, and oak can be found in the pure form, and, though not very often, they form mixed stands with each other or other coniferous or deciduous trees, especially chestnut (*Castanea sativa*) and Alder (*Alnus glutinosa*).

The total population of the rural settlements and that of Yığılca, which is the largest settlement within the study area, are depicted in graphs in Figure 2, which are based on data collected from the censuses conducted between 1965 and 2010. A total of 18% of the population lives in Yığılca town center, and the remaining

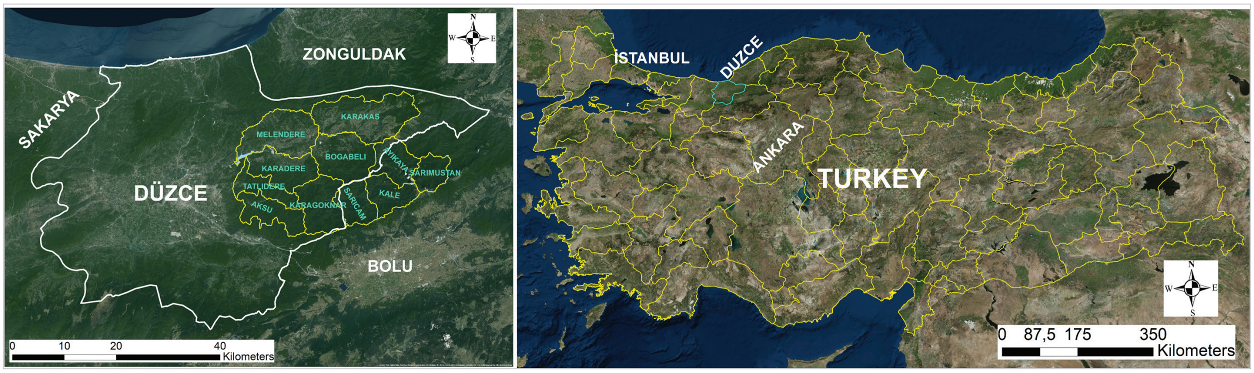

Figure 1. Location of the study area

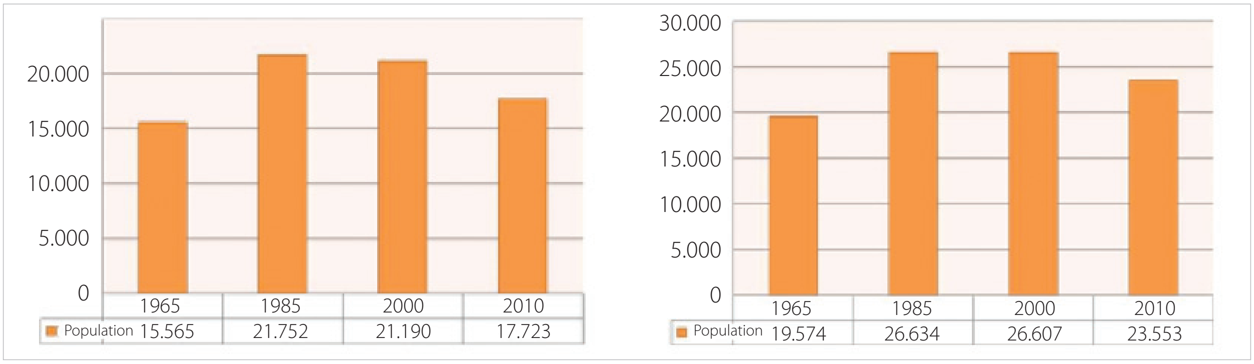

Figure 2. Temporal changes in population in Yığılca town center (left) and villages (right)

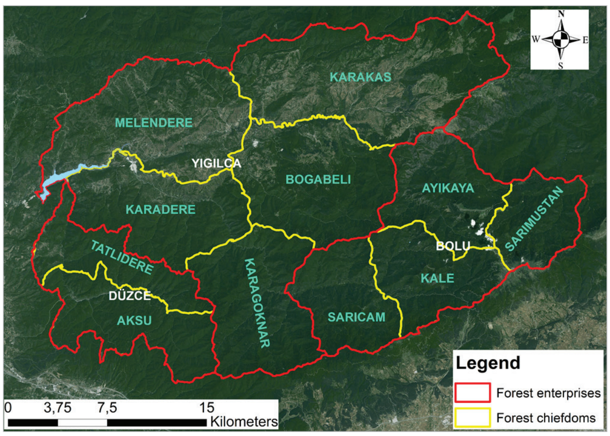

Figure 3. Forest enterprises and chiefdoms located within the study area

82% lives in rural areas. It can be observed that the population has decreased steadily since 1985. The town loses its population to big cities due to inefficient terrain and the lack of industrialization (Anonymous, 2014). Some of the people living in the villages tend to move to the highlands to spend the hot summer months and engage in agricultural activities. In addition, seasonal workers arrive from the eastern provinces, especially for hazelnut harvest. Therefore, during the summer months, a temporary population density is observed on forest roads and in lands adjacent to the forests.

Within the study area, three forest enterprises (FEs) are located and 11 FC areas operate under these departments. The FCs include Ayıkaya, Kale, Sarıçam, and Sarımustan that are affiliated to Bolu FE; Tatlıdere and Aksu that are affiliated to Düzce FE; and Boğabeli, Melendere, Karadere, Karagöknar, and Karakaş that are affiliated to Yığılca FE. The entire area of these FCs, except Melendere, is included in the study area, while 91% of Melendere is within the study area. Figure 3 shows the FEs and FCs located within the study area.

The Yığılca FE constitutes the majority of the study area, and 65.2% of the overall area of Yığılca FE is composed of forested areas. About 97% of this forested area consists of productive forests. When the entire study area is taken into account, more than half (56.8%) consists of forested area and the remaining 43.2% consists of deforested areas. Of the forested area, 97.1% is productive and the rest is degraded. Productive forests are usually mature in age and consist of thin or medium-sized sawtimber stands (Anonymous, 2015).

Preparation and Analysis of Digital Data

To examine the temporal changes in land use in the study area, first, 1/25,000-scale topographic maps and forest management plans of the study area that were prepared for the previous periods were obtained from Bolu Regional Directorate of Forestry using current management plans for the area. Stand maps of the year 1986 belonging to FCs within the study area were scanned at high resolutions and digitized using ArcGIS Desktop

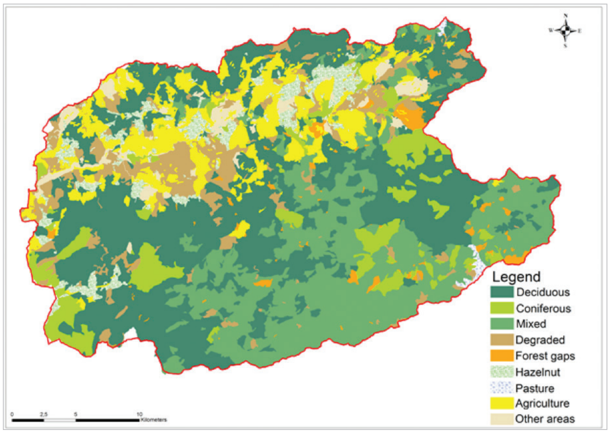

Figure 4. Distribution of land-use classes in 1986

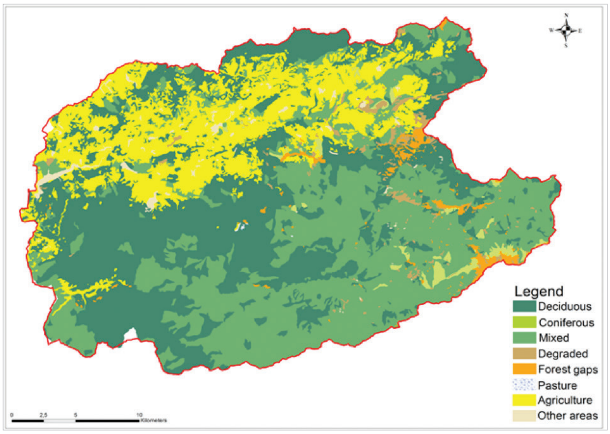

Figure 5. Distribution of land-use classes in 2010

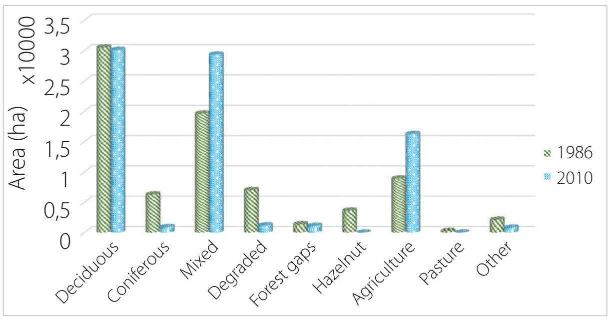

Figure 6. Areal distribution of land-use classes in 1986 and 2010

10.4 TM, a GIS software. The stand maps of 2010 were readily obtained in the digital form from the FEs and were analyzed for land classification. Aliases of stand types in the study were classified according to land-use types. In this manner, six classes, including forest, forest gaps, hazelnut, agriculture, pasture, and other fields, were categorized. Areas such as residential area, lake, depot, and mine were identified within other area classes. The forest areas were divided into groups of deciduous forests, coniferous forests, mixed forests, and degraded forests. The mixed forest group was not divided into subgroups to avoid increasing the number of groups. The supplied country maps were digitized using GIS, and the boundary of the Hasanlar Dam basin, which constitutes the study area, was determined by obtaining the digital elevation model of the area. After digitizing the stand maps for the FCs in the study area, the attribute tables were also organized for each period. Databases created in the GIS were then transferred to Microsoft Excel, and the temporal changes in land-use patterns were evaluated.

RESULTS AND DISCUSSION

Land-use Status of 1986

Through the digitization of the 1986 stand maps, it was observed that 82% of the Hasanlar Dam basin is composed of forest areas. The percentiles of the types of forests in the forested areas are as follows: 38% of the area (30,520 ha) comprised deciduous forests, 25% (19,621 ha) had mixed forests, 8% (6,301 ha) was composed of coniferous forests, and 9% (7,022 ha) of the area comprised degraded forests. Agriculture, hazelnut, pasture, and other areas made up a total of 18% of the total area (Figure 4).

Land-use Status of 2010

In 2010, it was observed that deciduous forest areas comprised the same proportion as that of the previous period (38%; 30,118 ha), but there was a loss of 402 ha of area. The proportion of mixed forest areas increased by 12% (9,730 ha) compared to that of the previous period, which was a 37% increase of the total area (28,945 ha). The proportion of coniferous forest areas decreased by 7% (5,384 ha) compared to that of the previous period at the rate of 1% (917 ha). Similarly, degraded forest area proportion decreased by 7% (5,827 ha) compared to that of the previous period at the rate of 2% (1,195 ha). With the decrease in the degraded forest areas and also considering hazelnut areas as agricultural areas, there was an increase of 9% (6,495 ha) in the agricultural areas, suggesting a 20% increase in the agricultural areas of the total area (15,420 ha). In addition, there were small decreases in other land-use classes (Figure 5).

The changes in land-use patterns in 11 FCs located in the Hasanlar Dam basin during this 24-year period are depicted in Figures 6 and 7.

Land-use Changes between 1986 and 2010

Land-use changes during the years 1986–2010 are presented in Table 1 and Figure 8. It can be observed that there was a huge transition from deciduous forests to mixed forests, and 2,660 ha of deciduous forests was converted into agricultural areas. Although there was a transition from deciduous forest land to other land-use classes, this transition was not in very large proportions. Regarding the changes that occurred in the coniferous forest areas, it there was a large decrease in this period and more than half of the coniferous forest areas turned into mixed forest areas. Moreover, there were transitions from coniferous forest areas to deciduous forest areas. The mixed forest areas also showed more than a 50% increase in this period, which amounted to 29,351 ha from 19,621 ha. Along with this increase in mixed forest areas, there

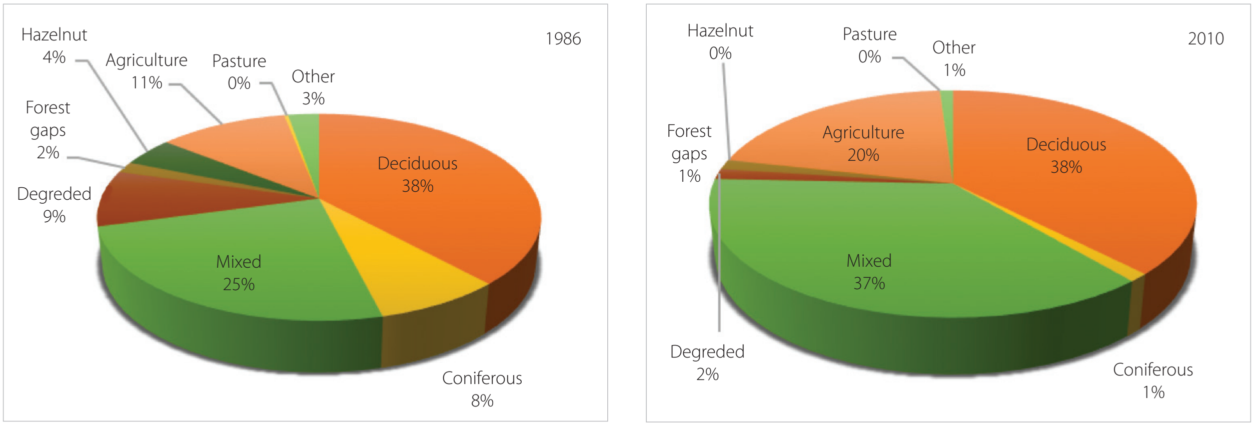

Figure 7. Distribution of land-use classes as percentages in 1986 and 2010

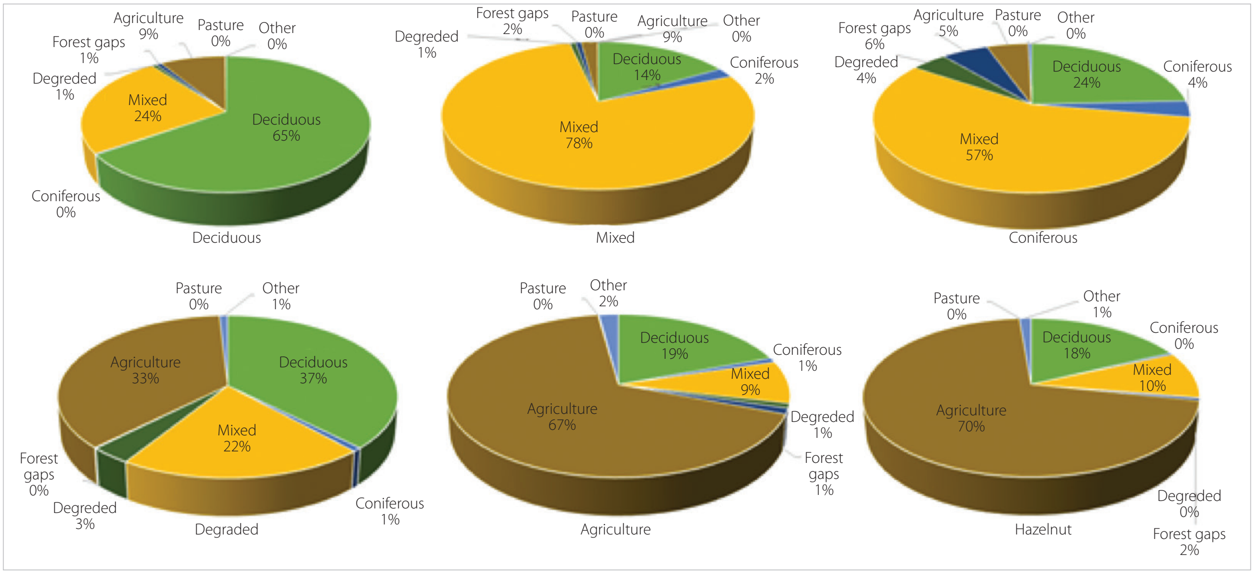

Figure 8. Proportional changes and transitions in land use between 1986 and 2010

Table 1. Land-use changes and transitions between 1986 and 2010

		Land use in 2010 (ha)								
	Land-Use Status	Decidu-ous	Conifer-ous	Mixed	Degra-ded	Forest Gaps	Agricul-ture	Pasture	Other	TOTAL
Land use in 1986 (ha)	Deciduous	19859,1	61,4	7482,7	194,3	234,7	2660,4	0,0	27,5	30520,2
	Coniferous	1526,5	220,2	3578,6	274,3	357,9	318,3	0,0	25,8	6301,6
	Mixed	3262,0	426,5	15242,0	147,3	138,9	392,8	1,7	10,0	19621,1
	Degraded	2632,7	54,9	1453,2	244,4	10,8	2562,9	0,0	63,7	7022,6
	Forest Gaps	368,3	41,5	329,4	199,8	121,4	306,7	5,6	4,7	1377,4
	Hazelnut	648,1	13,8	344,0	4,2	18,7	2559,2	0,0	47,7	3635,7
	Agriculture	1730,3	78,9	749,2	85,0	103,6	5981,2	11,1	186,0	8925,4
	Pasture	5,6	16,0	83,6	19,8	141,8	0,0	0,3	0,0	267,1
	Other	85,2	4,2	88,7	25,9	0,0	638,7	0,0	460,0	1302,6
	TOTAL	30117,8	917,4	29351,4	1195,0	1127,9	15420,1	18,7	825,3	78973,6

Table 2. Change in land use over the years (ha)

Year	Forest	Hazelnut	Agriculture	Pasture	Other	Total (ha)
1986	64843	3635	8925	267	1303	78973
2010	62709	0	15420	19	825	78973

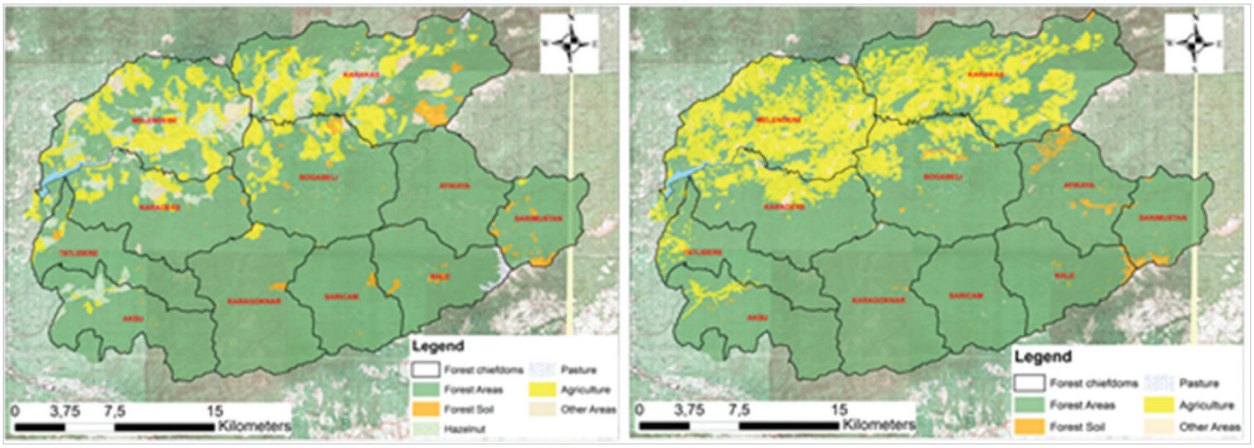

Figure 9. The spatial status of land-use patterns in 1986 (left) and 2010 (right).

were transitions to other land-use types as well. The transition to the mixed stands was primarily from the deciduous and coniferous forest areas, whereas the mixed forest areas were primarily converted into deciduous forest areas.

There was a significant decrease in the degraded forest areas during 1986–2010. Although this decline was effective for the rehabilitation of degraded forests into productive deciduous forests, transformation of the degraded forest areas into agricultural areas due to the crimes of the local people, such as for occupation, illegal cutting, and clearing, is also noticed as another reason for the decrease in the degraded forest areas. There was no significant change in the land-use status of forest gaps. Although the agricultural areas were converted into deciduous forest areas, considering the hazelnut areas as agricultural areas in the 2010 forest management plan stand maps was especially the primary reason for the increase in agricultural areas.

During the period under study, it can be observed that the forest areas (deciduous, coniferous, mixed, and degraded forests) decreased by about 2,130 ha between 1986 and 2010, from its initial level of 64,843 to 62,709 ha. This decrease was primarily due to the increase in the agricultural areas in the forest areas. There was a 42% increase in agricultural areas between these two periods (Table 2).

The general land-use statuses of 1986 and 2010 are depicted in Figure 9. All the subgroups, without dividing the forested areas, were evaluated under the forest major group to visually assess the primary changes.

The forest management discipline attempts to ensure that forest areas are regulated in line with the demands of the community through forest management plans and monitors the changes in these resources over the periods according to the inventory it has compiled. Land-use patterns are determined by the forest management teams through 10- or 20-year plans. The work of these teams is of vital importance in preparing stand maps. Due to these reasons, it is very important for the people in forest management teams to have the knowledge and experience for comprehending land-use patterns and the ability to anticipate future outcomes of the decisions they make in the determination of land-use patterns and follow-up changes.

A decrease of about 3% (2,133 ha) occurred in the forest areas during the period 1986–2010 (Table 2). When deciduous forests are evaluated, in general, although there was a small spatial decrease in the period between 1986 and 2010, there was no proportional change between these two periods. There were transitions from deciduous forests to other land-use types and from other land-use types to deciduous forest areas. A total of 65% of the deciduous forests was preserved as spatial distribution in the process from 1986 up to the year 2010. During this period, coniferous forests lost their dominance and were transitioned to deciduous and mixed forest cover types. The largest change in area and proportion of land use was observed in the mixed forest areas. The proportion of mixed stands with an area of 25% (19,621 ha) in 1986 increased to 37% (29,351 ha) during the period up to the year 2010, especially in the deciduous and coniferous forest areas, through the transformation of their mixed status with natural processes and management interventions, turning into mixed forest status, and with the rehabilitation or reforestation of degraded forests. In their studies at Duzce-Cumayeri region on land-use changes during the period 1987–2010, Sivrikaya et al. (2011) observed similar increases in deciduous and mixed forest areas as those achieved in the present study, along with a decrease in coniferous and degraded forest areas. The findings of the increase in the deciduous and mixed forest areas due to the transitions from coniferous forest areas are effective. The reforestation operations in the degraded forests using the deciduous species and, especially, the result of the transition to deciduous forests are similar to those of the present study.

Although there was no significant difference in population between the 1985 census (26,634) and the 2000 census (26,607) in the villages within the study area, there was a decrease of approximately 13% between 2000 and 2010 (23,553). Several studies (Gümüş et al. 1996; Ateşoğlu and Tunay 2010; Özsan 2011; Bayar 2003) have indicated that population growth has a negative impact on forest areas and natural resources and that these areas are declining. However, in the study of Kadıoğulları and Başkent (2007) on the spatial and temporal dynamics of Gümüşhane during the years 1970–2000 and in the study of Günlü et al. (2008) on land-use changes in Rize between 1970 and 2000, the authors concluded that there was a decrease in both the population and forest areas. In the present study, it was observed that despite the decrease in the population between 2000 and 2010, there was no increase in the forest areas, but a decrease in forest areas was observed during this period. This situation indicates that other factors may also influence land-use changes. That is why it can be observed that the increase in the pressure in the forest areas is not always directly proportional to the increase in population. This is because, besides forestry operations, biotic and abiotic damages can also cause a change in forestlands. Thus, there may be changes in the structural elements of the stands (such as species mixture or standing stock), although there is not always a land-use change that leads to deforestation. In addition, it is observed that previous forest destruction activities maintain the current state, and the forest continues to be used for activities such as grazing and agriculture. It has been observed that some activities generally protect the forests, such as raising the awareness of the people, attaching more importance to the protection of forests by enacting laws, successful forestation, and the formation of income-generating resources, which have now come to the forefront.

The hazelnut areas in the stand maps of 1986 were not included in the stand maps of 2010. This was due to the fact that the hazelnut areas were not included in the distribution charts for land-use types in the Statement on Procedures and Principles Regarding the Preparation of Ecosystem-based Functional Forest Management Plans (OGM 2014). This is why the inclusion of the entire land-use pattern of hazelnut areas into agricultural areas in the management plans resulted in considering hazelnut areas as being transformed. This is primarily due to the fact that the hazelnut areas were not removed from the ground, but only the land-use patterns were changed for agriculture. In the period of analysis, some of the hazelnut areas were transformed into forest areas and most of them (2,559.2 ha) were considered as agricultural areas with only a change of name.

Regarding the agricultural areas, there was a 42% increase from 1986 until the year 2010. Considering the land-use patterns of hazelnut areas as agricultural areas in 2010 was particularly responsible for this increase. In addition, there were transitions to agricultural areas, especially from the deciduous (2,660.4 ha) and degraded forests (2,562.9 ha). Sivrikaya et al. (2011) determined a 5% increase in agricultural land between 1987 and 2008 in their study on land-use changes in the Düzce–Cumayeri region. They concluded that the major cause for the increase in agricultural area in that region was the consideration of the fields indicated by hazelnut aliases in the agriculture plans as agricultural areas. Gülersoy (2013) found that agricultural land had increased by 71% between 1987 and 2011, despite a 62% reduction in rural population, and stated that this stemmed from the conversion of pastures and bottom lands into agricultural areas. The reason for this observation is expressed as an increase in food demand and the exploitation via agriculture. In the study conducted by Doygun (2012), agricultural areas were reported to decrease by 58%, for which the author stated that the agricultural lands were converted into forest areas due to the successful forestation activities.

Although there were minor changes in other land-use classes, there was a decrease and transition to agricultural areas. In other areas, residential areas occupied a large amount of space, and it could be understood that the transitions were primarily caused due to the changes in these areas. This situation is believed to be caused not by the physical change in the area but by the representation of the stand type alias in the stand type maps. In this case, it was effective to change some of the aliases that were shown as Z-Is in the previous period and that showed the cases where both the agricultural and the residential areas were intertwined to indicate only the agricultural areas in the new period. On the other hand, the designation of the residential areas as smaller polygons in the new period, which had been drawn as larger polygons in the previous period, including the surrounding agricultural areas, led to a decrease in the amount of other areas.

CONCLUSION

Due to the scope of the study, while the maps were digitized in terms of land-use forms, cadastre and ownership conditions were not considered, and only the status of the land reflected on the stand maps was analyzed. For example, a place that was transformed into an agricultural field was still considered as an agricultural area even though it was still in the forest status. Therefore, the effects of possible sources of error that may occur during the preparation of the stand maps were ignored and the stand maps were analyzed assuming the maps to be accurate. Various errors can occur in the preparation of stand maps using a combined inventory during the interpretation of aerial photographs, satellite images, and terrestrial measurements, which are based on temporary sample plots. Some forest stands that were missed in the previous inventory period may have been reflected in the map in the subsequent period, and some areas that were merged under the same type may have later been expressed as a separate type.

In such studies using GIS, it is necessary to acquire a large number of control points while transforming old stand type maps into actual coordinates. Otherwise, even if the outer boundaries of the maps to be compared overlap, the glitches within the boundaries of the inner polygon that depict the stand boundaries may not be removed. This may lead to the perception that the periodically unchanged areas have been converted into different forms of land use when the overlay analysis is carried out. If this situation is not taken into consideration, the analysis will not be very healthy.

Based on the results of the present study, in addition to the transitions within the forest areas, in the period between 1986 and 2010, the forest areas decreased by about 3% (2,134 ha) and there were large-scale transformations into agricultural areas. Through the Melen project, water is being transported from the Hasanlar Dam to İstanbul. Since changes in land use can affect the quantity and quality of water supplied from the dam basin, it is necessary to keep these changes under control. Illegal land use should be prevented, cadastral work should be completed, and forest boundaries should be determined. Although the population in the study region has been gradually decreasing during the period of analysis, the agricultural areas have increased. There is a need for activities to reduce the pressure on the forests by increasing the income level of the people living in this region.

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Original Article

Surface glossiness properties of wood impregnated with some plant extracts

Bazı bitkisel ekstraktlar ile emprenye edilen ağaç malzemelerin yüzey parlaklık özellikleri

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ABSTRACT

This study investigated the changes in surface glossiness after 100 and 300 h of accelerated weathering of beech wood (*Fagus orientalis* L.) that was coated with polyurethane and cellulosic and water-based varnishes after impregnation with 5% and 10% concentrations of mimosa (*Acacia mollissima*) and quebracho (*Schinopsis lorentzii*) extracts and 4.5% Tanalith-E. The highest glossiness values were observed in the untreated control samples before and after accelerated weathering. Moreover, except for the samples coated with polyurethane varnish, the surface glossiness values of other samples decreased after accelerated weathering. Among the varnish types, the polyurethane varnish showed the best result in terms of surface glossiness, with higher values being observed after the 100-h weathering period than those before weathering. Increasing the tannin concentrations from 5% to 10% resulted in a decrease in the glossiness values. Wood impregnated with mimosa and quebracho extracts and varnished with polyurethane was able to maintain both durability and surface glossiness for a longer time.

Keywords: Tannin, varnish, accelerated weathering, glossiness

ÖZ

Bu çalışmada, %5 ve %10 konsantrasyonlarda mimoza (*Acacia mollissima*) ve kebrako (*Shinopsis lorentzii*) ekstraktları ve %4,5'lik Tanalith-E ile emprenye edilen kayın (*Fagus orientalis* L.) odunundan hazırlanan deney örnekleri poliüretan, selülozik ve su bazlı vernikler ile üst yüzey işlemine tabi tutulmuştur. 100 ve 300 saatlik hızlandırılmış yaşlandırma sonrasında yüzey parlaklığında meydana gelen değişimler araştırılmıştır. Elde edilen sonuçlara göre, yaşlandırma öncesi ve yaşlandırma sorası en yüksek parlaklık değerleri emprenye edilmemiş kontrol örneklerinde elde edilmiştir. Ayrıca poliüretan verniği haricinde genel olarak yaşlandırma işlemi ile birlikte vernik yüzeylerindeki parlaklık değerlerinde azalma meydana gelmiştir. Vernik çeşitleri içerisinde en iyi parlaklık değerleri poliüretan verniğinde elde edilmiştir. 100 saat yaşlandırma işlemine tabi tutulan poliüretan vernikli deney örnekleri kontrol örneklerine göre daha yüksek parlaklık değeri vermiştir. Tanenler ile emprenye edilen örneklerde konsantrasyon seviyesi %5'ten %10'a arttırıldığında parlaklık değerlerinde belli oranlarda azalma görülmüştür. Bu sonuçlara göre, mimoza ve kebrako ekstraktları ile emprenye edilen ağaç malzemeler poliüretan verniği uygulanarak hem dayanıklılıkları hem de yüzey parlaklıkları uzun süre korunabilir.

Anahtar Kelimeler: Tanen, vernik, hızlandırılmış yaşlandırma, parlaklık

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INTRODUCTION

Wood materials can be used for more than 10,000 applications. Their renewability; anatomical structure; physical, mechanical, and chemical properties; and easy machinability provide several advantages. In contrast, their hygroscopic nature is responsible for some negative aspects such as the lack of dimensional stabilization. Moreover, wood being an organic material is susceptible to destruction by biotic factors such as insects and fungi (Budakci, 2003). Numerous problems have also been recognized to be encountered in outdoor applications of wood materials, which include color change, glossiness deterioration, and the formation of surface roughness and cracks due to the effects of ambient conditions (humidity, UV, etc.) (Feist, 1982; Kartal, 1992; Williams, 2005). These negative features of wood materials can be reduced or minimized using various impregnation processes and surface treatments. In addition, the esthetic aspect of the wood can be enhanced or maintained (Kurtoğlu, 1984; Evans et al., 2005; Soylamış, 2007; Temiz et al., 2007).

From the past till today, various impregnation materials for wood have been developed to improve both indoor and outdoor long-term uses. With the application of these impregnation materials, the resulting increase in the service life of wood products provides both technical and economic benefits for the users. In addition, the long-term use of wood materials indirectly contributes to the sustainability of forests, despite the fact that several impregnants used in the past few years have been restricted or totally prohibited in several European countries due to adverse environmental effects (Kartal et al., 2006; Cao et al., 2011). Therefore, efforts have been recently increasing for the development of impregnation materials that would be both environmentally friendly and not hazardous to human health. Several studies have been conducted on the possibility of utilizing plant extracts, especially for the impregnation of indoor wood materials. These studies have determined that plant extracts are effective against the insects that cause the destruction of wood (Şen, 2002; Clausen and Yang, 2007; Tascioglu et al., 2012; Tascioglu et al., 2013). In this study, two commercial herbal extracts, namely, mimosa and quebracho, were used as impregnation materials. Mimosa extract is obtained by hot water extraction from the bark of *Acacia mollisima* tree and contains 33% of condensed tannins. Quebracho extract is obtained by hot water extraction from the wood of *Schinopsis lorentzii* tree and contains about 20% of condensed tannins (Huş, 1965). Chemical analyses of both extracts have revealed the presence of phenolic compounds such as catechol, epicatechin, and several fatty acids (Yalcin, 2012), which indicates the antifungal properties of these extracts (Ichihara and Yamaji, 2009; Pohl et al., 2011).

Wood contains hydroxyl functional groups such as hydroxyl, carbonyl, and carboxyl groups and aromatic and phenolic groups (Zhang et al., 2009). Under outdoor weather conditions, first, the color of the wood surfaces changes and the brightness decreases and then the roughness increases and various cracks appear. These modifications occur in the chromophore groups of the wood (Temiz et al., 2007; Zhang et al., 2009). Surface glossiness, which is the mirror-like reflection of light, is a very important feature for the esthetic and decorative appearance of wood surfaces (Çakıcıer et al., 2011). This is why it is essential to preserve the quality of the surface treatment so that the glossiness can be maintained for a long time on the wood surface where the treatment was applied.

Several factors are known to influence the glossiness of varnished surfaces, including climatic factors (Çakıcıer, 2007), tree type, varnish layer thickness, varnish application method (Sönmez et al., 2004), surface smoothness, and light reflection (Şanıvar, 1978). The chemicals used for the impregnation of wood materials have also been reported to be effective factors (Yalinkilic et al., 1999; Soylamış, 2007; Kesik, 2009; Baysal et al., 2013). After the impregnation process, structural wood materials require a surface treatment before use. Varnishing has been a preferred method of surface treatment in terms of reflecting the natural structure of the wood. That is why it is essential to determine the effects of impregnants on the surface treatments.

The primary purpose of this study was to examine the effects of treatment with environmentally friendly herbal extracts such as mimosa and quebracho on the surface glossiness values of oriental beech (*Fagus orientalis* L.) wood. In addition, different varnish applications and the changes in glossiness of the impregnated wood were evaluated under different accelerated weathering periods. This made it possible to determine the type of varnish application that best preserved the esthetic properties of the wood impregnated with the extracts.

MATERIALS AND METHODS

Materials

Within the scope of this study, samples of beech wood (*F. orientalis* L.) were prepared according to TS 4176 (1984) standard. Since beech sapwood has a *diffuse porous* structure that can be easily impregnated, it can provide suitable results for both impregnation and surface treatments (Bozkurt et al., 1993). The samples were cut with dimensions of 32 × 8 × 2 cm (length × radial tangent). The surfaces of the test specimens were sanded using 80-, 120-, and 150-grit sandpaper, respectively, until they reached a constant weight at 20°C±2°C and 65%±5% relative humidity (TS 642 ISO 554, 1997).

Mimosa (*A. mollissima*) bark extract and quebracho (*S. lorentzii*) wood extract prepared at concentrations of 5% and 10% were used for the impregnation of the experimental samples. Tanalith-E (4.5%) was used for comparison.

Within the scope of the study, the following three different varnish types were used: polyurethane and cellulosic and water-based varnishes. Each varnish type exhibited different behaviors when applied to the surfaces. Therefore, the effects of the different varnish applications on post-impregnation glossiness values were examined and compared.

Method

Impregnation process

The beech wood samples were first impregnated with mimosa and quebracho extracts to assess the effect of the varnish on the surface glossiness. Prior to impregnation, the oven-dry weight of the test samples was determined by drying them at 60°C for 48 h (m_0). The impregnation process was carried out in a vacuum-pressurized impregnation cylinder. An initial vacuum of 600 mmHg was applied for 20 min, and then a pressure of 12 bar was applied for 30 min. After the impregnation process, the wet weights (m_1) of the samples were measured and the retention amounts were calculated according to the following formula (TS 5723, 1988).

$$\text{Retention} = \frac{GxC}{V} x10 kg/m^3 \quad (1)$$

In the formula:
$G = (m_1 - m_0)$ (g),
C = Solution concentration, and
V = Volume of the wood sample (cm^3).

Varnish application

Varnish application was conducted in accordance with the manufacturer's recommendation. After the preparation of the varnishes for application, a finishing coat was applied using a spray gun. All the samples were dried under room temperature conditions after varnishing. The application viscosities of the varnishes were determined to be 15 snDIN/4 mm for polyurethane and 17 and 32 snDIN/4 mm for the cellulosic and water-based varnishes, respectively.

Accelerated weathering process

The tannins and surface varnishes used in this study were subjected to accelerated weathering to investigate the changes in the varnished surface glossiness, especially under the influence of abiotic (UV, temperature, etc.) factors under outdoor conditions. The weathering process was carried out in accordance with ISO 4892-3 (2005) using a UV-A 340 lamp in a calibrated QUV instrument (Figure 1a). For the weathering process, the conditioning program consisted of 0.76 UV W/m^2 for 8 h at 60°C and for 4 h at 50°C. The differences in the unweathered and weathered specimens are shown in Figure 1b.

Glossiness measurements

The measurements of surface glossiness of the wood parallel to the grain were conducted on all the samples after impregnation, varnishing, and weathering. Measurements were performed using a glossiness measuring device (a glossmeter) at an angle of 60° and using a calibrated surface according to the principles specified in ISO 2813 (1994) (Figure 1b). The glossiness values were measured both before weathering and after 100 and 300 h of accelerated weathering. A total of 810 measurements were performed, comprising 15 replications for each group.

Statistical Analyses

The effects of the impregnation material, the varnish type, and the weathering process on the glossiness of the varnished surfaces were statistically determined using the SPSS package program. All the variables were analyzed using Analysis of variance (ANOVA). Duncan's test with 95% confidence level was used to compare the mean values of the groups. The glossiness values according to the levels of impregnation, the varnish type, and the weathering period were compared.

RESULTS AND DISCUSSION

The retention amounts obtained with the impregnation process are shown in Table 1. The results show that there was no statistical difference in the retention amounts between the tannin species. In addition, the amounts of varnish applied per square meter for the polyurethane and cellulosic and water-based varnishes were determined to be 150, 130, and 130 g/m^2, respectively.

The average glossiness values of the varnished surfaces in terms of impregnation application are shown in Table 1. The highest glossiness values were detected in the unimpregnated control samples, whereas the lowest values were observed in the samples impregnated with mimosa and quebracho tannins at 5% concentration. These results indicate that when the samples were impregnated with Tanalith-E and tannins, there was a statistically significant decrease in the average glossiness values. In addition, when the concentration of each tannin was increased from 5% to 10%, there was again a statis-

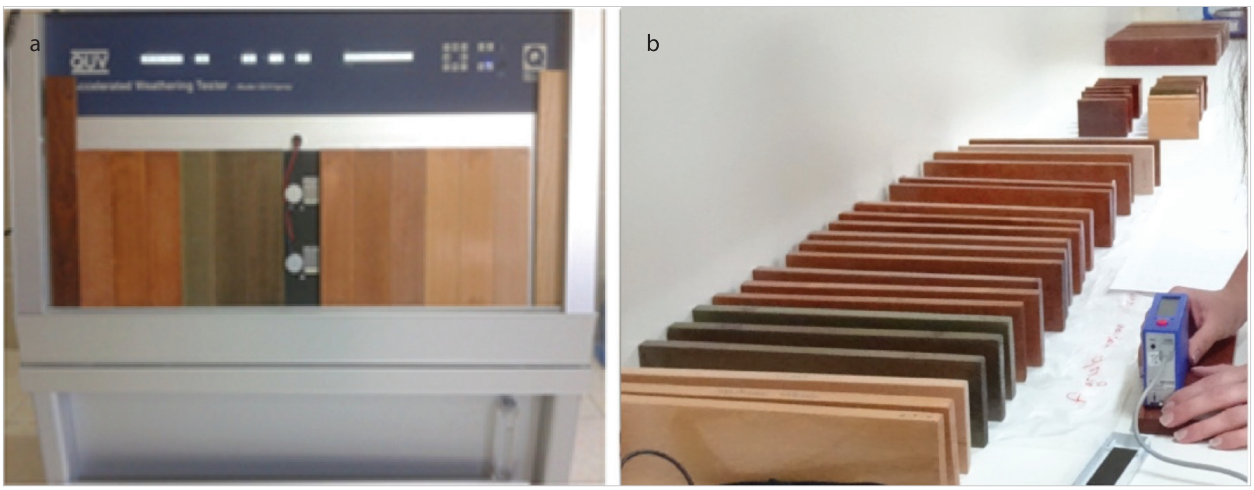

Figure 1. a, b. (a) Accelerated weathering, (b) Glossiness measurement

Table 1. Effects of impregnation on the glossiness of varnished surfaces

		Retention (kg/m³)		Mean glossiness parallel to grain	
Impregnation	Number of samples	Average	HG**	Average	HG**
Control	135	-	-	50.6	a*
4.5% Tanalith-E	135	55.68	b*	36.3	c
5% Mimosa	135	37.52	c	43.1	b
10% Mimosa	135	76.17	a	37.2	c
5% Quebracho	135	38.44	c	38.3	bc
10% Quebracho	135	76.42	a	33.8	d
P value (Significance)*		0.000		0.000	

*Values followed by the same letter are not significantly different ($p<0.05$), HG: Homogeneity group, *$p<0.05$.

Table 2. Effects of varnish application on surface glossiness (average of impregnation and weathering)

Varnish type	n	Mean glossiness parallel to grain	
Polyurethane	270	58.5	a*
Cellulosic	270	23.0	c
Water-based	270	38.1	b
P value (Significance)*		0.000	

*Values followed by the same letter are not significantly different, N: Number of sample, *$p<0.05$.

Table 3. Effects of weathering application on surface glossiness (average of impregnation and varnishing)

Accelerated weathering	n	Mean glossiness parallel to grain	
Before weathering	270	42.9	a
100 h	270	40.3	a
300 h	270	36.6	b
p value (Significance)*		0.000	

*Values followed by the same letter are not significantly different, N: Number of sample, *$p<0.05$.

tically significant reduction in the glossiness values. The lowest mean glossiness value was obtained with the 10% quebracho extract. The glossiness values were decreased in the wood samples treated with water-based impregnation materials (Özdemir et al., 2015).

The average glossiness values in terms of the varnish type are shown in Table 2. The results indicate that the highest average glossiness was observed in the polyurethane-varnished samples (58.5), while the glossiness values of the samples coated with water-based and cellulosic varnishes were 38.1 and 23.0, respectively. The difference in the glossiness values according to the varnish types may have been caused due to factors such as the drying systems and the chemical composition of the varnishes. It is believed that polyurethane varnish imparts a high glossiness value compared to that with other varnish types because of the chemical solidification between the varnish molecules together with the intermolecular cohesion (Soylamış, 2007).

The samples impregnated with tannins and Tanalith-E showed decreased glossiness values because of the water-based properties of these chemicals. Water-based impregnation materials have been reported to cause the fibers to swell and the surfaces to become rough (Yakın, 2001). Some studies have reported higher glossiness values with solvent-based impregnants, which have been shown to result in better filling of the wood surface and light reflection (Özdemir et al., 2015). It has also been reported that the low glossiness values in impregnated samples could be caused due to the impregnation materials adding their own chemical structures to the wood material surface (Soylamış, 2007).

Table 4. Effects of the interaction of weathering and impregnation on the surface glossiness of samples treated with polyurethane and cellulosic and water-based varnishes

Accelerated weathering	Impregnation	Number of samples	Polyurethane		Cellulosic		Water-based	
Control	Unimpregnated	15	76.2	a*	40.8	b*	45.2	bcd*
	4.5% Tanalith-E	15	45.9	ef	14.2	hl	38.3	ef
	5% Mimosa	15	53.4	e	33.0	gh	53.9	a
	10% Mimosa	15	52.2	de	18.0	c	47.6	bc
	5% Quebracho	15	57.1	g	26.5	de	50.2	ab
	10% Quebracho	15	45.4	de	28.9	d	47.0	bcd
100 h	Unimpregnated	15	81.7	a	45.7	a	32.3	g
	4.5% Tanalith-E	15	56.8	c	13.8	hl	46.7	bcd
	5% Mimosa	15	61.4	de	23.8	ef	35.2	fg
	10% Mimosa	15	57.7	bc	22.8	ef	33.3	fg
	5% Quebracho	15	55.8	g	20.8	fg	33.4	fg
	10% Kebrako	15	53.9	c	16.2	hl	29.3	gh
300 h	Unimpregnated	15	75.8	ab	24.4	ef	33.3	fg
	4.5% Tanalith-E	15	52.9	e	14.6	hl	43.1	cde
	5% Mimosa	15	63	cd	22.7	ef	41.4	de
	10% Mimosa	15	55.3	e	22.2	efg	25.6	g
	5% Quebracho	15	54.4	e	13.3	l	33.0	fg
	10% Quebraco	15	53.3	e	12.6	hl	17.8	l
	p value (Significance)*		0.000					

*Values followed by the same letter are not significantly different, *$p<0.05$.

The average glossiness values according to the weathering time periods are shown in Table 3. According to the statistical results, the highest average glossiness value (42.9) was obtained in the unweathered samples. However, there was no statistically significant difference among the samples weathered for 100 h. The lowest average glossiness value (36.6) was found in the samples after 300 h of weathering. Previous studies have shown that the effect of UV light on the surface glossiness was limited by weathering (Scrinzi et al., 2011; Baysal et al., 2013). Accelerated weathering causes erosion and roughness on the surfaces, thereby decreasing the surface glossiness values. Moreover, together with the weathering process, breakages in the varnish layer may also cause a decrease in the glossiness values (Çakıcıer, 2007).

Table 4 shows the differences in glossiness values with accelerated weathering of the impregnated and varnished samples.

Compared with the glossiness of the polyurethane-varnished samples, high glossiness values were obtained in the unimpregnated control samples, with the values being 76.2 before weathering, 81.7 after 100 h of weathering, and 75.8 h after 300 h of weathering. Baysal et al. (2005) also reported an increase in the glossiness values with weathering, depending on the varnish type. This increase could be attributed to the complete curing of the varnishes during the weathering process, and this process has been believed to be the basis for the increase in glossiness (Çakıcıer, 2007).

When the concentration of the impregnation materials was increased from 5% to 10%, it was observed that the glossiness values of the samples impregnated with tannins were reduced by a certain percentage. The highest glossiness value was obtained in the samples impregnated with quebracho extract (57.1) before weathering. After weathering, the highest glossiness value was obtained in the samples impregnated with 5% mimosa extract. Compared with the glossiness values before weathering, it was observed that the glossiness values of the polyurethane-varnished samples increased by 20% after the 100-h weathering process. Although there was a decrease in the glossiness value of the samples impregnated with 5% quebracho extract, it was not statistically significant (Figure 2).

When the glossiness values of the samples coated with cellulosic varnish were examined, in general, the highest glossiness values were obtained in the unimpregnated control samples. Statistical analysis of the results of the control samples showed

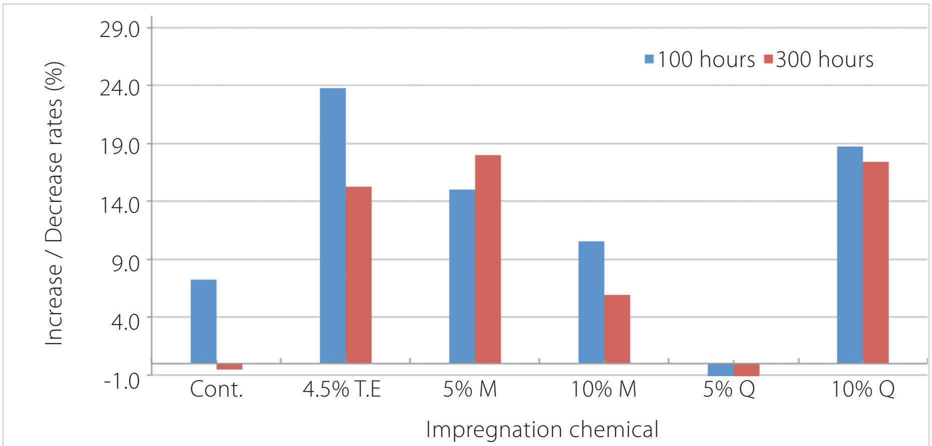

Figure 2. The rate of change in the glossiness values of polyurethane-varnished samples compared with those before weathering

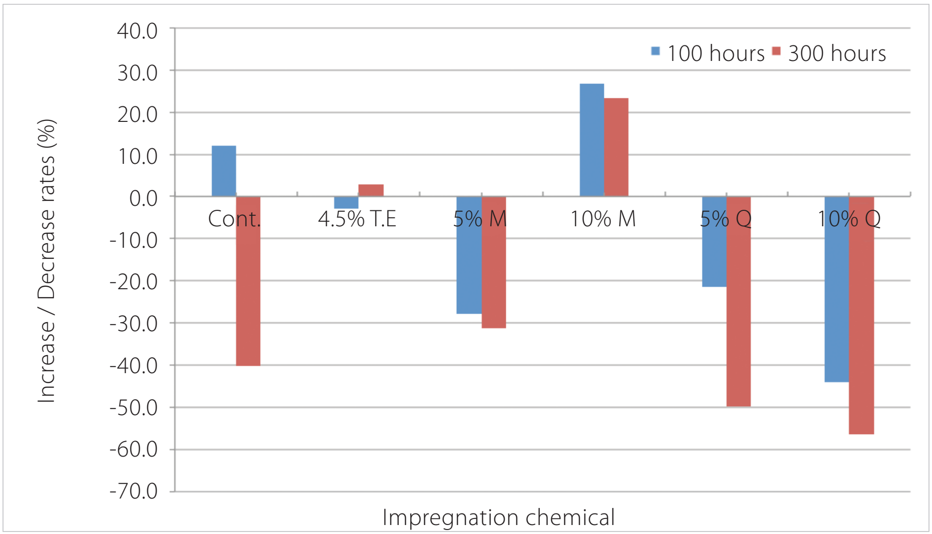

Figure 3. The rate of change in the glossiness values of samples treated with cellulosic varnish compared with those before weathering

the highest glossiness value of 45.7 at the end of the 100-h weathering period. In general, the highest glossiness values of the impregnated specimens were found in those impregnated with 5% mimosa extract. The glossiness values of the specimens impregnated with 5%-10% quebracho extract were significantly decreased, but there was no statistically significant change in the glossiness values of the Tanalith-E-impregnated specimens after weathering. In general, the weathering process had a decreasing effect (by 50%) on the glossiness of the samples treated with cellulosic varnish after 300 h of weathering compared to that of quebracho extract-impregnated specimens (Figure 3). Baysal et al. (2005) reported that the changes in the glossiness values were dependent on the impregnation chemicals and that after the weathering process, the glossiness values of the test specimens were decreased, whereas they showed an increase in some experimental specimens due to impregnation and the varnish type.

Regarding the samples coated with the water-based varnish, in general, the highest glossiness values were obtained in the unweathered samples. However, the highest glossiness value was found in those impregnated with Tanalith-E after 100 h of weathering. Moreover, it was observed that when the concentration levels of the chemicals in the impregnated samples were increased from 5% to 10%, there was a decrease in the glossiness values before and after weathering. The lowest glossiness value was observed in the samples impregnated with 10% quebracho extract (17.8). When compared with the glossiness values of unweathered specimens, besides those impregnated with Tanalith-E, a 60% decrease was observed in the glossiness values with weathering (Figure 4).

Based on the findings of this study, the impregnation process appears to have had a negative effect on the glossiness of the varnished surface. Similar results as well as those that differed

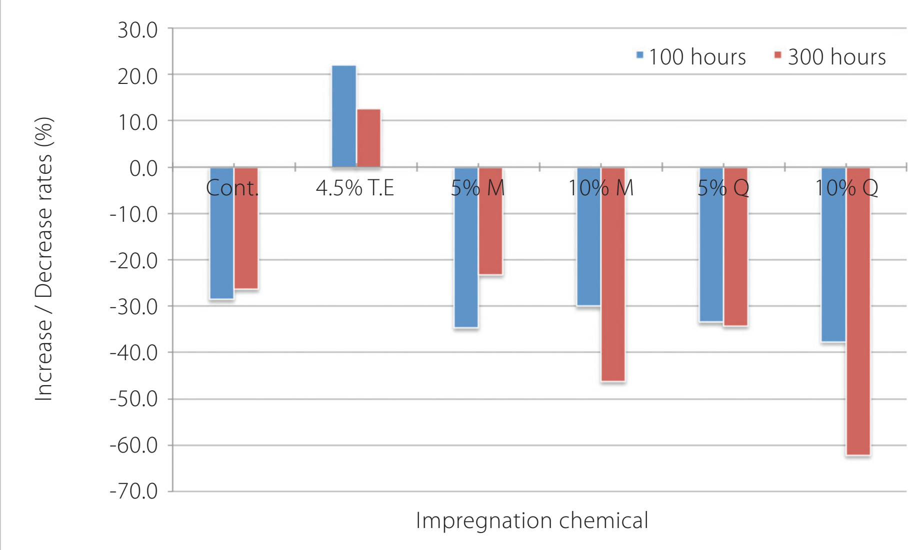

Figure 4. The rate of change in the glossiness values of samples coated with water-based varnish compared with those before weathering

could be found in the literature. Baysal et al. (2013) showed that CCB and Tanalith-E impregnants had a decreasing effect on the surface glossiness values of specimens coated with both cellulosic and polyurethane varnishes. Similarly, Topgül et al. (2009) stated that some boron compounds caused a reduction in surface glossiness with weathering. However, Özdemir et al. (2015) found that, at the end of their study, the glossiness values of Scots pine, beech, and chestnut samples without impregnation were higher than the glossiness values of samples impregnated with CCA, Tanalith-E, and boric acid and lower than those of samples impregnated with solvent-based immersol aqua.

In particular, it was noted that the control samples coated with cellulosic and water-based varnishes showed a significant decrease in their glossiness values when the weathering time reached 300 h. This result indicated that the decrease in the glossiness with weathering of the samples impregnated with tannins was caused not only due to the effect of the tannins but also due to the natural structure of the wood material. In addition to accelerated weathering, the effects of UV rays, heat, and rain can cause photochemical reactions, by which the surface glossiness changes due to the formation of free radicals from these reactions (Zahri et al., 2007; Rosu et al., 2010).

CONCLUSION

The glossiness of a varnished surface can be significantly affected by factors such as impregnation with tannins, the varnish type, and the accelerated weathering process ($p < 0.05$, Tables 1–3). When the effects of tannins on the glossiness of the varnished surface were examined, the highest glossiness values were observed in the control samples without impregnation. When the average values of all three varnish treatment types were taken into consideration, it was observed that the impregnation application and varnished surface glossiness values were reduced at different rates. In addition, with the increase in the tannin concentration ratio, there was again a decrease in the glossiness values. However, in the samples subjected to surface treatment with polyurethane varnish, the glossiness decreased after a certain weathering period (100 h) and after that (300 h), the glossiness values increased. In the samples coated with cellulosic varnish, the control samples without impregnation showed the highest glossiness values under all weathering conditions. The impregnation process was found to decrease the glossiness values, and the lowest glossiness values in the samples coated with cellulosic varnish were obtained in the quebracho tannin-impregnated samples after the 300-h weathering period. For the water-based varnishes, it was observed that with the weathering process, there was a decrease in the surface glossiness values of both the impregnated and the unimpregnated samples.

These results indicate that both mimosa and quebracho extracts can be considered as natural and environmentally friendly impregnation chemicals for wood materials, which could maintain the durability and esthetic features of wood for a long time along with the application of polyurethane varnish.

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Original Article

Investigation on slope and canopy closure effects to minimize sediment movement in riparian buffer zone

Tampon zonlarda sediment üretimini en aza indirmek için eğim ve meşcere kapalılığının etkisi üzerine bir araştırma

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ABSTRACT

In this study, factors affecting the width of buffer zone used to minimize the sediment movement in the productive forests, have been evaluated. For this purpose, sediment traps were constructed in İstanbul University Education Research and Practice Forest. Sediment data was obtained from sample plots established depending on the different canopy closure, slope length, slope area, rainfall and slope. In this context, a statistical model was developed to estimate the sediment yield depending on slope and canopy closure. The accuracy of the model was tested with various statistical analyses. According to the results, sediment value can be highly estimate depending on slope classes. According to results, in the developed regression models to estimate effects of slope percentage on sediment values, the smallest R2 value was found as 0.79 on 20 % slope area and the highest R2 value was found as 0.97 on 80 % and 100 % slope area. Also, as the slope increases, the accuracy of the regression model of sediment yield increases. And it is concluded that there is a very close relationship between 80 % and 100 % slope. In the developed regression models to estimate effects of canopy closure effects on sediment values, it is seen that the lowest R2 value was calculated on canopy closure 71-100 %, and the highest R2 values were calculated on canopy closure 41-70 % and cutting areas. Sediment yield increases with the decrease of the canopy closure and the accuracy of the model increases.

Keywords: Sediment movement, buffer zone, forest area

ÖZ

Bu çalışmada, üretim ormanlarındaki sediment hareketini en aza indirgemek için kullanılan tampon zon alanlarının genişliğini etkileyen faktörler değerlendirilmiştir. Bu amaçla, İstanbul Üniversitesi Eğitim Araştırma ve Uygulama Ormanı'nda sediment kapanları tesis edilmiştir. Farklı meşcere kapalılığı, yamaç uzunluğu, yamaç alanı, yağış ve eğime bağlı olarak tesis edilen deneme alanlarından sediment verisi alınmıştır. Bu kapsamda, sediment verimini hesaplamak amacıyla istatiksel bir model ortaya konmuştur. Modelin doğruluğu çeşitli istatistiksel analizlerle sınanmıştır. Sonuçlara göre, eğim sınıflarına bağlı olarak sediment değeri yüksek oranda tahmin edilebilmektedir. Elde edilen sonuçlara göre, eğim yüzdesine bağlı olarak olarak sediment tahmini için geliştirilen regresyon modeli sonuçlarında en düşük R2 değeri %20 eğim sınıfında 0.79, en yüksek R2 değeri %80 ve %100 eğim sınıflarında 0,97 olarak bulunmuştur. Ayrıca eğim arttıkça regresyon modelinin doğruluğu arttığı görülmüş ve %80 ile %100 eğim sınıfları arasında çok yakın bir ilişki bulunmuştur. Ayrıca meşcere kapalılığının sediment üretimi üzerindeki etkisini araştırmak için üretilen regresyon modelinde en düşük R2 değeri %71-100 meşcere kapalılığında, en yüksek R2 değerleri ise %41-70 kapalılıkta ve traşlama kesimlerinin yapıldığı alanlarda hesaplanmıştır. Meşcere kapalılığının azalmasıyla birlikte sediment üretimi ve modelin doğruluğu artmaktadır.

Anahtar Kelimeler: Sediment taşınması, tampon zon, ormanlık alan

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INTRODUCTION

Riparian zone is a type of ecotone, or boundary between ecosystems like many other ecotones. Riparian buffer zones are exceptionally rich in biodiversity (Gregory et al, 1991, Malanson, 1993, Naiman et al., 1993).

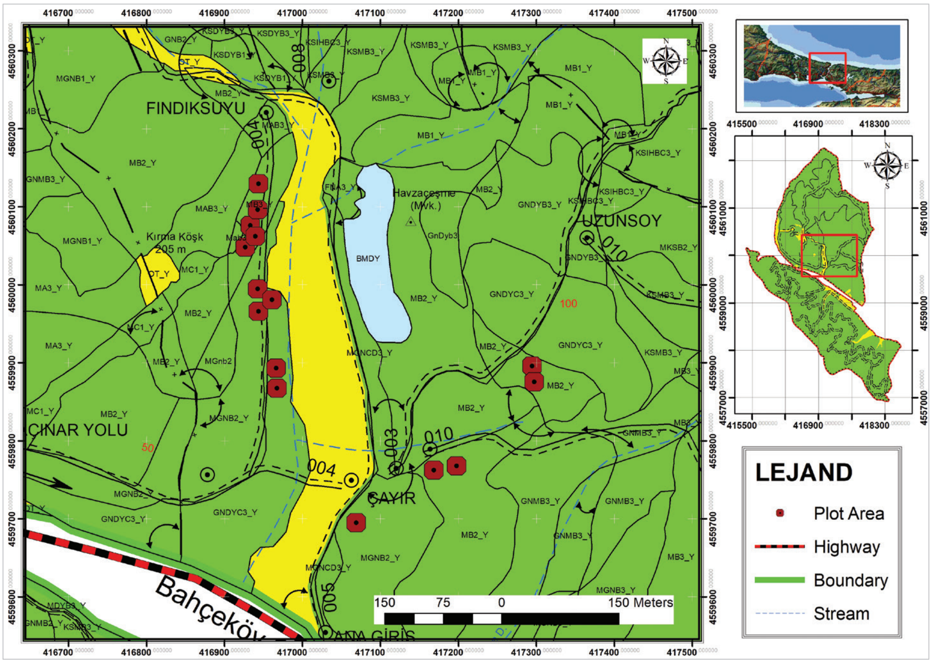

Figure 1. The location of study area and sediment traps (Akgul, 2012)

A riparian zone that is afforded to some degree of protection is a riparian buffer zone. The Word "buffer" is used because one of the functions of the protected area is to buffer the stream from the impact of human land use activities, such as farming and construction (Wenger, 1999). Depending on this various activities, the natural structure is deteriorating and there is accumulation of sediment in the streams.

Trapping and/or removing sediment from runoff is one of the important functions of Riparian buffers (Wood and Armigate, 1997; Malanson, 1993; Wenger and Fowler, 2000; Bentrup, 2008; Schueler, 1995, Rudeck et al, 1998, Akgul, 2012).

Some of the first research on riparian buffers was initiated to determine logging road setbacks (Trimble and Sartz, 1957). Sediment trapping efficiency of riparian buffer zones depends on many factors. The buffer width is one of the most important aspects of the effectiveness. Large buffers generally remove more pollutants than smaller ones. The effectiveness of buffer zone width is influenced by various factors, e.g. slope, vegetation type, soil type, rainfall etc. (Mayer et al, 2005)

One of the greatest factor is the slope to minimize the sediment movement in the riparian buffer zone. The slope factor is used in many formulas which is developed for calculating the effective buffer width to prevent the sedimentation and other pollutants. Some of these formulas are based on only slope factors.

Another factor is the soil type which is not recommended because of determining soil characteristics on wide scale somewhat is problematic and expensive (Wenger, 1999).

Vegetation type is also effective factor. Both forested and grass buffers are effective to trapping sediment. The combination of vegetation types (trees, grass and shrubs) helps maximize the efficiency and diversity of benefits that the buffer provides. Removal sediment efficiency range from 70-90% forested area, 53-97 % of the vegetated filter strip, 92-96 % of forested and vegetated filter strips (Krumine, 2004).

In this study, slope and canopy closure factors were investigated to effectiveness of buffer zone on sediment trapping/production rate.

MATERIALS AND METHODS

Study Area

Field monitoring study was done in İstanbul University Education Research and Practice Forest which is located in northern part of İstanbul. The research field is at Thracian side of Marmara Region, between 28° 59′ 17″-29° 32′ 25″ east longitudes and 41° 09′ 15″–41° 11′ 01″ north latitudes according to Greenwich (Figure 1).

Construction of Plot Areas and Sediment Traps

In the study, plot areas and the sediment traps were constructed in research forest to determine riparian buffer zone effectiveness ratio for minimize the sediment and calculating the sediment yield. While sample plots are choosing, canopy closure, slope and slope length were considered. The sediment traps are constructed in 4 different plot areas (Pa) which have different canopy closure. Plot areas' canopy closures range from 0% of clear cutting area (Pa1), 10-40% of Pa2, 41-70% of Pa3, 71-100% of Pa4. Totally 120 sediment traps were estab-

Figure 2. Sediment traps in plot areas (Akgul, 2012)

lished at 5 different slopes (20%-40%-60%-80%-100%), and 10 different slope lengths (1-10 meters), in each plot areas (Figure 2) (Akgul, 2012).

Collecting Sediment Data

Sediment data were collected from the sediment traps within after each heavy rainfall. Totally 19 different rainfalls occurred during study between first data collection and last data collection. First sediment data was collected in November 28, 2010, last sediment data was collected May 8, 2011. After each heavy rainfall, sediment data were collected from sediment traps and labelled in sample container to be analyzed in the laboratory (Akgul, 2012).

Sediments which collected from sediment traps were separated from materials such as branches, leaves in the laboratory. During the study, totally 4544 sediment data which were taken from sediment traps and they were weighted after dried at 150°C in laboratory (Figure 3).

Meteorological Data

Weather data was continuously recorded at the adjacent weather station at the Green Roof Research Site located in İstanbul University Faculty of Forestry. Weather data was measured by an automated weather station (DeltaOhm HD2003). Three axis Ultrasonic Anemometer, Delta OHM S.r.L., Padova/Italy, measurement accuracy ±1°C) and precipitation measurements were collected using a rain gauge (DeltaOhm HD 2003 tipping bucket, measurement accuracy ±1%). All meteorological data was collected by hourly.

Statistical Evaluation of Sediment Data

In the study, all statistical analysis was performed using Minitab 16.0 statistical package. Multiple linear regression analysis was used to find the statistical relationship between dependent (sediment) variables and independent variables (slope, slope length, slope area, canopy closure, precipitation). Simple linear regression analysis was used to bilateral relations between parameters to mathematically.

To evaluate and examine statistically the relationship between the independent variables and the dependent variable with its relationship correlation analysis was used. To evaluate accuracy of developed mathematical model by regression analysis, total number of variables (n=4544) were randomly selected and used as calibration data, while approximately 25% of them (n=1136) were also used as test data. And also paired sample T Test and

Figure 3. Evaluation of the sediment data (Akgul, 2012)

Table 1. Rainfall data of sediment data collection

	Rainfall			
Data No	Date	Month	Year	Rainfall (mm)
1	23-27	November	2010	25
2	5-6	December	2010	13.4
3	10-11	December	2010	58.4
4	13-17	December	2011	13.3
5	3-7	January	2011	33.4
6	16-17	January	2011	16.4
7	22-27	January	2011	50.3
8	29-30	January	2011	11.1
9	15-20	February	2011	10.8
10	22 - 2	February-March	2011	43.8
11	6-11	March	2011	13.1
12	17-19	March	2011	11.5
13	20-21	March	2011	15.2
14	27 - 2	March-April	2011	31.4
15	3-6	April	2011	9.7
16	8-15	April	2011	17.3
17	18-19	April	2011	28.1
18	20-29	April	2011	13.4
19	30 - 7	April-May	2011	46.1

correlation analysis were used to calculate the significance level of the models.

RESULTS

Results of Meteorological Data

During sediment data collection totally 19 different rainfalls occurred. The lowest rainfall occurred in April 3-6, 2011 with 9.6 mm. The highest rainfall occurred in December 10-11, 2010, with 58.4 mm (Table 1).

Results of Sediment-Slope

In order to estimate effects of slope percentage on sediment values, five different multiple regression models were developed. In all regression models sediment value ln(Sed) was consider as dependent variable. Also, in all models; slope length [ln(Sl)], canopy closure [ln(Ccl)], total precipitation [ln(Tp)] and area [ln(Ar)] were considered as independent variables. According to model 1 which developed to estimate [ln(sed)] value Adjusted R^2 found as 0.79 for 20% slope value, in model 2 found as 0.88 for 40% slope value, found as 0.93 for 60% slope value, found as 0.97 for 80% slope value and Adjusted R^2 found as 0.97 for 100% slope value. The results were showed that sediment value can be highly estimate depending on slope classes (Table 2, 3).

Within the scope of the study, to validation of developed regression models test datasets were used. Scatter plot model 1 for 20% slope, was demonstrated a linear correlation with R^2=0.88 between observed and predicted ln(sed) (225 observations), model 2 for 40% slope was demonstrated linear correlation with R^2=0.88 between observed and predicted ln(sed) (228 observations), model 3 for 60% slope was demonstrated linear correlation with R^2=0.94 between observed and predicted ln(sed) (228 observations), model 4 for 80% slope was demonstrated linear correlation with R^2=0.97 between observed and predicted ln(sed) (228 observations), while model 5 for 100% slope was demonstrated linear correlation with R^2=0.96 between observed and predicted ln(sed) (228 observations) (Figure 4) (Akgul, 2012).

Results of Sediment-Canopy Closure

In order to estimate effects of canopy closure percentage on sediment values, three different multiple regression models were developed. In all regression models sediment value ln(Sed) was consider as dependent variable. Also, in all models; slope length ln(Sl), slope ln(P), total precipitation ln(Tp) and area ln(Ar) were considered as independent variables. According to model 1 which developed to estimate ln(sed) value depending on canopy closure 71-100%, Adjusted R^2 found as 0.92. In model 2 which developed to estimate ln(sed) value depending on canopy closure 41-70%, Adjusted R^2 found as 0.96 while in model 3 which developed to estimate ln(sed) value depending on canopy closure 41-70%, Adjusted R^2 calculated as 0.96 (Table 4, 5) (Akgul, 2012).

In the scope of the study, to validation of developed regression models test datasets were used. Scatter plot model 1 for 71-100% canopy closure, was demonstrated a linear correlation with R^2=0.914 between observed and predicted ln(sed) (381 observations), model 2 for 41-70% canopy closure was demonstrated linear correlation with R^2=0.914 between observed and predicted ln(sed) (380 observations), model 3 for canopy closure 0% (clear cutting area) was demonstrated linear correlation with R^2=0.940 between observed and predicted ln(sed) (376 observations) (Figure 5).

Table 2. Statistical summary of regression models

Model No	Slope Constant	N	Adjusted R2	Std. Error of the Estimate	F	Sig.
1	20	896	0.79	0.58	844.71	0.000
2	40	912	0.88	0.35	1659.37	0.000
3	60	912	0.93	0.25	2987.81	0.000
4	80	912	0.97	0.16	7302.61	0.000
5	100	912	0.96	0.20	4956.39	0.000

Table 3. Summary of regression model coefficients

Model no	Slope %	Model	B	Regression Model
Model 1	20	Constant	-0.340	$Y=e^{-3.40-0.602*\ln(Sl)-2.030*\ln(Ccl)+0.765*\ln(Tp)+1.011*\ln(Ar)}$
		ln(Sl)	-0.602	
		ln(Ccl)	-2.030	
		ln(Tp)	0.765	
		ln(Ar)	1.011	
Model 2	40	Constant	0.118	$Y=e^{0.118+0.773*\ln(Sp)-1.254*\ln(Ccl)+0.469*\ln(Tp)+1.020*\ln(Ar)}$
		ln(Sl)	-0.773	
		ln(Ccl)	-1.254	
		ln(Tp)	0.496	
		ln(Ar)	1.020	
Model 3	60	Constant	0.394	$Y=e^{1.020-0.80*\ln(Sp)-1.045*\ln(Ccl)+0.422*\ln(Tp)+1.020*\ln(Ar)}$
		ln(Sl)	-0.800	
		ln(Ccl)	-1.045	
		ln(Tp)	0.422	
		ln(Ar)	1.020	
Model 4	80	Constant	0.583	$Y=e^{0.583-0.77*\ln(Sp)-1.088*\ln(Ccl)+0.461*\ln(Tp)+1.021*\ln(Ar)}$
		ln(Sl)	-0.774	
		ln(Ccl)	-1.088	
		ln(Tp)	0.461	
		ln(Ar)	1.021	
Model 5	100	Constant	0.680	$Y=e^{0.680-0.736*\ln(Sp)-1.224*\ln(Ccl)+0.567*\ln(Tp)+1.021*\ln(Ar)}$
		ln(Sl)	-0.736	
		ln(Ccl)	-1.224	
		ln(Tp)	0.567	
		ln(Ar)	1.021	

DISCUSSION AND CONLUSION

Sediment trapping efficiency of riparian buffer zone is one of the most important factor of buffer zone effectiveness to determine optimum buffer width. Many factors were investigated to determine effectiveness of buffer zones. Especially, slope factor has been studied in many studies. In the scope of the study, slope factor and canopy closure factor were evaluated to investigate the effects of closure and slope on sediment production in the study.

The most extensive investigations of the relationship between slope factor and sediment production to determine buffer width effectiveness have been conducted by forestry

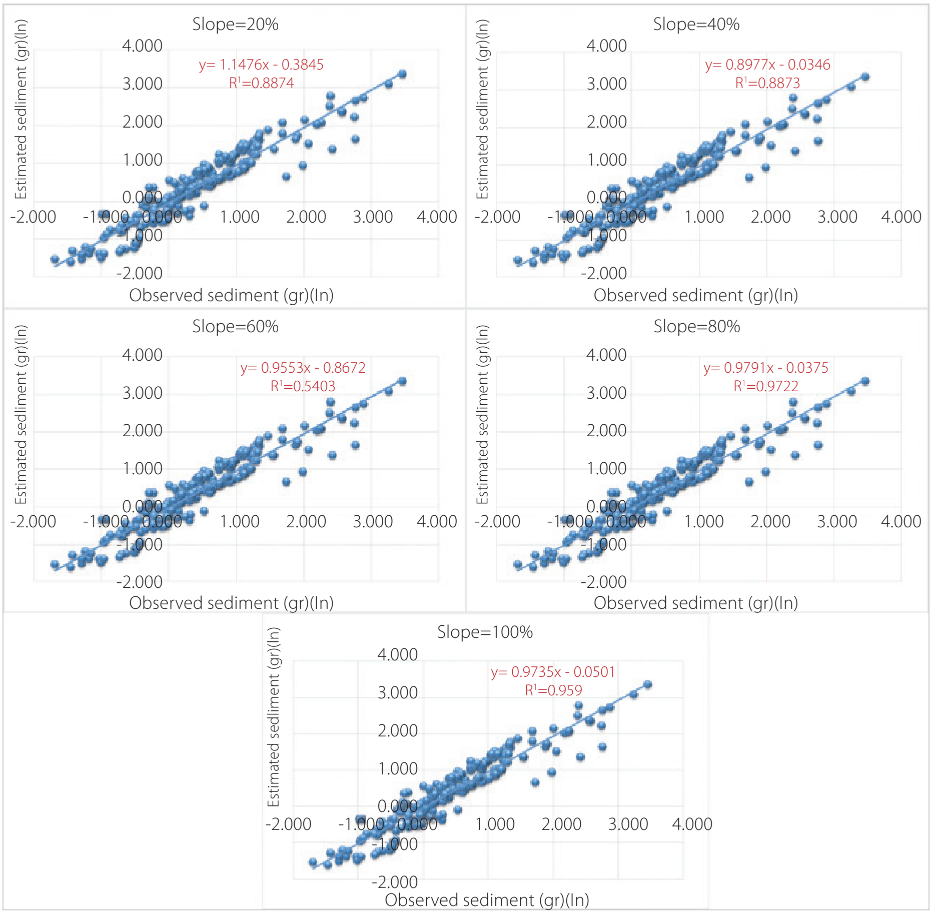

Figure 4. Validation of estimated and observed sediment values according to slope

Table 4. Statistical summary of regression models

Model No	Canopy Closure %	N	Adjusted R2	Std. Error of the Estimate	F	Sig.
1	71-100	1520	0.92	0.31	441.207	0.000
2	41-70	1520	0.96	0.18	9230.914	0.000
3	0-40	1504	0.96	0.19	8216.685	0.000

researchers. Trimble and Sartz (1957) found a high correlation between slope and buffer width in the formula they developed. This formula also shows a strong relationship between slope and sediment production. Dillaha et al. (1988, 1989) indicated that as buffer slope increase from 11% to 16%, sediment trapping of buffer zone declined by 7-38%. According to results, in the developed regression models to estimate effects of slope percentage on sediment values, the smallest R^2 value was found as 0.79 on 20% slope area and the highest R^2 value was found as 0.97 on 80% and 100% slope area. According to these results, as the slope increases, the accuracy of the regression model of sediment yield increases (Akgul, 2012). And it is concluded that there is a very close relationship between 80% and 100% slope. Also, R^2 values and the normal R^2 values are close to each other reveal the correctness of the model. It was showed that it can be highly estimate depending on slope class.

Also several studies were conducted to investigate effectiveness of vegetation type to sediment trapping on riparian buffer zone. Some of researchers suggested grass buffer while other researcher suggested forested buffers. Also, Welsch, 1991, Lowrance et al, 1997 strongly suggest a combination of grass and forested buffers to increase effectiveness of buffer zone to minimize sediment production. Krumine in 2004 stated that removal sediment efficiency range from 70-90% forested area, 53-97% of the vegetated filter strip, 92-96% of forested and vegetated filter strips. According to results, in the developed regression models to estimate effects of canopy closure effects on sediment values, it is seen that the lowest R^2 value

Table 5. Summary of regression model coefficients

Model no	Slope %	Model	B	Regression Model
Model 1	71-100	Constant	-7.486	$Y=e^{-7.486-0.645*ln(Sl)+1.237*ln(P)+0.683*ln(Tp)+1.028*ln(Ar)}$
		ln(Sl)	-0.645	
		ln(P)	1.237	
		ln(Tp)	0.683	
		ln(Ar)	1.028	
Model 2	41-70	Constant	-3.335	$Y=e^{-3.335-0.777*ln(Sl)+0.594*ln(P)+0.476*ln(Tp)+1.007*ln(Ar)}$
		ln(Sl)	-0.777	
		ln(P)	0.594	
		ln(Tp)	0.476	
		ln(Ar)	1.007	
Model 3	0-40	Constant	-2.839	$Y=e^{-2.839-0.790*ln(Sl)+0.605*ln(P)+0.465*ln(Tp)+1.019*ln(Ar)}$
		ln(Sl)	-0.790	
		ln(P)	0.605	
		ln(Tp)	0.465	
		ln(Ar)	1.019	

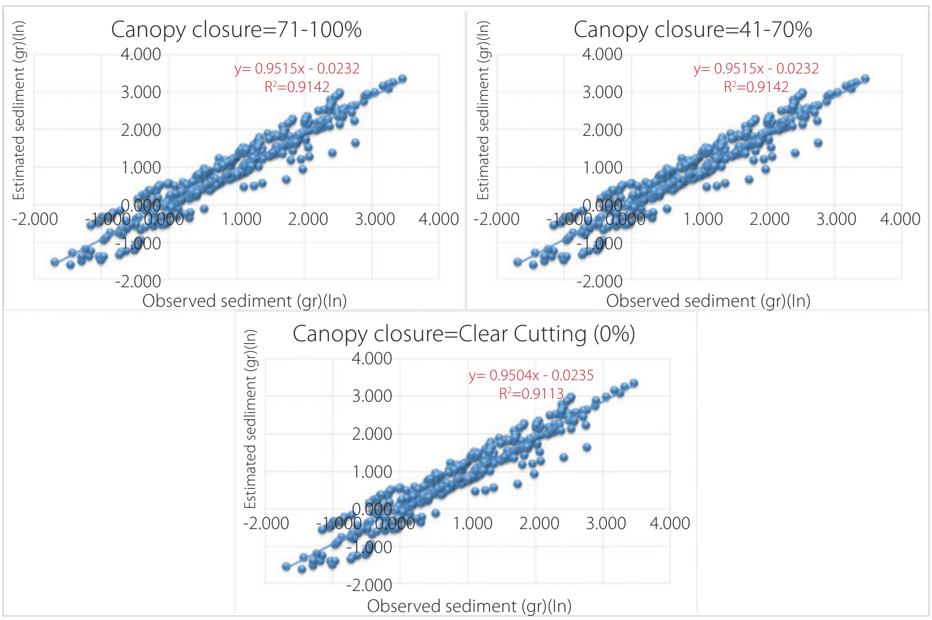

Figure 5. Validation of estimated and observed sediment values according to canopy closure

was calculated on canopy closure 71-100%, and the highest R^2 values were calculated on canopy closure 41-70% and cutting areas. Sediment yield increases with the decrease of the canopy closure and the accuracy of the model increases. As is also implied, according to test data, the generated regression model is statistically acceptable.

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