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The relationships between environmental and disturbance factors in temperate deciduous forest ecosystem (Amasya/Turkey)

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Ilıman yaprak döken ormanlarda (Amasya/Türkiye) tahribat ve çevresel faktörler arasındaki ilişkiler

Abstract: Deciduous forests face many disturbance factors. Grazing and cutting are the leading factors in this disturbance. The study area's vegetation was analyzed using numerical methods to identify plant communities and determine the relationship between environmental gradients and disturbance factors. The species diversity was calculated using alpha and beta diversity indexes. As a result, four different communities were identified in the study area. One of the communities was under grazing pressure while the other community was under cutting pressure. No disturbance factors were found in the remaining two communities. Elevation and soil moisture were found to be important in the distribution of plant communities. pH, soil moisture, soil % N content and canopy factors were found to be important. The highest Shannon-Wienner diversity index values were found in non-cutting and non-grazing forest communities. The lowest Shannon-Wienner diversity index values were found in grazing and cutting forest communities. Unlike the Shannon-Wienner diversity index, the highest beta index values were found in grazing and cutting forest communities. The lowest beta index values were found in non-cutting and non-grazing forest communities.

Key words: Plant ecology, plant diversity, numerical method

Özet: Yaprak döken ormanlar birçok tahribat faktörüyle karşı karşıyadır. Özellikle otlatma ve ağaç kesimi bu faktörlerin başında gelmektedir. Çalışma alanının vejetasyonu, bitki komünitelerinin tespiti ve çevresel faktörler ile tahribat faktörleri arasındaki ilişkiyi belirlemek için nümerik metotlar kullanılarak analiz edilmiştir. Tür çeşitililiği alfa ve beta çeşitlilik indeksleri kullanılarak hesaplanmıştır. Sonuç olarak, çalışma alanında 4 farklı komünite tespit edilmiştir. Bu komünitelerden biri otlatma baskısı altındayken diğer komünite ağaç kesimi baskısı altındadır. Diğer komüntelerde ise tahribat faktörleri bulunmamıştır. Rakım ve toprak neminin bitki komünitelerinin dağılımında önemli olduğu bulunmuştur. pH, toprak nemi, toprak N içeriği ve kanopi faktörleri önemli bulunmuştur. En yüksek Shannon-Wienner indeks değerleri ağaç kesimi ve otlatma olmayan orman komünitelerinde bulunmuştur. En düşük Shannon-Wienner çeşitlilik değerleri ise otlatma ve ağaç kesimi olan orman komüntelerinde bulunmuştur. Shannon-Wienner çeşitlilik indekslerinin aksine, en yüksek beta çeşitlilik indeks değerleri otlatma ve ağaç kesimi olan orman komünitelerinde bulunmuştur. En düşük beta index değerleri ağaç kesimi ve otlatma olmayan orman komünitelerinde bulunmuştur.

Anahtar Kelimeler: Bitki ekolojisi, bitki çeşitliliği, numerik metod

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1. Introduction

There are significant relationships between plant species and environmental factors in terrestrial ecosystems. Topography, soil characteristics and climatic conditions are determinants factors affecting plant diversity (Davies et al., 2007; Korkmaz et al., 2016). For example, soil pH (Borchsenius et al., 2004; Hofmeister et al., 2009), nutrient availability (Small and McCarthy, 2005; van Calster et al., 2008), soil moisture (Qian et al., 1997, Lenière and Houle, 2006), the mass of litter layer (Gazol and Ibánez, 2009; Kooijman, 2010), light availability (Härdtle et al., 2003; Tinya et al., 2009) and distance to forest edge (Harper et al., 2005; Gonzalez et al., 2010) are among the most critical environmental factors (Vockenhuber et al., 2011).

In temperate deciduous forests, approximately the 90% of vegetation consists of vascular plant diversity (Whigham, 2004; Gilliam, 2007). The composition and diversity of the ground flora in temperate deciduous forests are affected by the composition of the canopy species and soil and climate characteristics (Hunter, 1999; Augusto et al., 2003; Gilliam, 2007; Barbier et al., 2008). While underground vegetation contributes significantly to total biodiversity in temperate forests, it contributes less to total forest biomass (Gilliam, 2007).

There are many disturbance factors in temperate forests. Among these, grazing and tree cutting are among the most important. Grazing and tree cutting cause complexity and instability in species interactions (Fakhireh et al., 2012; Hüseyinova et al., 2013; Xu et al., 2016; Kılıç et al., 2018). The intensity of disturbance allows some species to establish, grow, and reproduce (Pierce et al., 2007; Duru et al., 2010; Frenette-Dussault et al., 2012; Kılıç et al., 2018).

In this study, we examined relationships among disturbance (grazing and tree cutting), environment factors (soil pH, soil nitrogen, soil moisture and light availability) and biodiversity in the temperate deciduous forest.

2. Materials and Method

The study area is located in the Yeşilırmak basin in the central region of Turkey. The study area is located between 400 m and 1100 m in altitude (Fig. 1). The study area has between oceanic and continental climates. The mean annual temperature and the mean annual precipitation are 13.9°C and 397.5 mm, respectively. The maximum mean temperature is 31.7 °C (August), while the lowest mean temperature is − 0.6 °C (January). The vegetation consists of Irano-Turanian and Mediterranean species. Natural flora has been affected by grazing and tree cutting.

Taxonomic nomenclature followed was that of Davis (1965-1985) and Davis et al. (1988), Tutin and Heywood (1964-1980), Güner et al. (2000) and Güner et al. (2012). Four plots were selected from floristically and structurally homogeneous places according to the goal of study. Ten relevés was established for each plot, and the size of plots was determined according to the minimal area method (Westhoff and van Der Maarel, 1978). A cover-abundance value for each species in each relevés was determined using the Braun-Blanquet (1964) scale.

Soil samples for each relevés were taken at a depth of 35 cm. Soil pH values were measured using deionized water (1:1) by pH meter (Kacar, 2012). Soil nitrogen was determined by the way of micro-Kjeldahl method (Bradstreet, 1954). Water content was determined by the gravimetric method (Bayrakli, 1987, Kutbay and Ok, 2003). Light availability was determined using a Lutron Light Meter LX-1102 (Schuster and Diekmann, 2005).

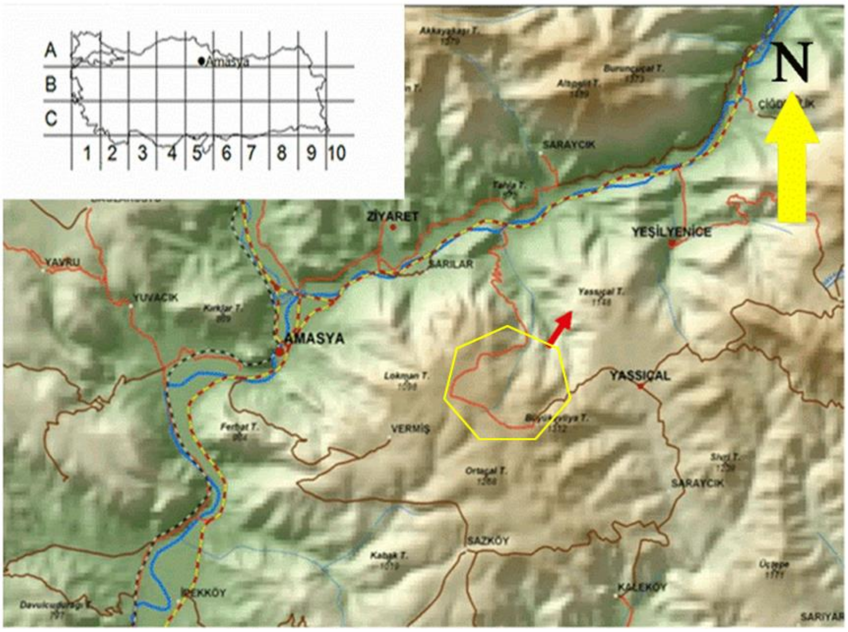

Figure 1. Map of the study area

The Shannon – Wienner diversity indices of the plant communities were calculated using the following formula (Magurran, 2004).

$$H = \sum_{i=1}^{s} pi \ x \ lnpi$$

"s" is the total number of recorded species, "pi" is the proportion of percentage cover of the "i"th species to the sum of the percentage cover of all species and ln is the natural logarithm.

Evenness was quantified using Shannon's indices. Indices of the plant communities were calculated using the following formula (Magurran, 2004).

$$J = H'/Hmax$$

where Hmax is maximum species diversity and calculated as $\log_2$ Pi.

Beta diversity is defined as spatial heterogeneity or pattern diversity was calculated using the Whittaker formula (Whittaker, 1960; Gulsoy and Ozkan, 2008).

$$\beta = S/\alpha - 1$$

where S is the total number of species, α is the mean species richness.

Plant communities according to disturbance factors were separated by using TWINSPAN procedure. To determine what environmental factors were significant, we also treated our data with Detrended Correspondence Analysis (DCA) and Principal Component Analysis (PCA). Numerical methods were performed by using the "Community Analysis Package 4 version" software (Seaby and Henderson, 2007).

Statistical analysis was performed by using a SPSS (25.0 version) software. The differences among plant communities were investigated by one-way ANOVA. The biodiversity parameters were assessed by Tukey's significant difference (HSD) test to rank the means.

3. Results

TWINSPAN analysis revealed four plant communities. They are grazing, non-grazing, cutting and non-cutting plant communities. Diagnostic species of the grazed area are *Acantholimon acerosum* (Willd.) Boiss. var. *acerosum*, *Achillea setacea* Waldst. et Kit, *Carduus pycnocephalus* L. subsp. *albidus* (Bieb.) Kazmi, *Globularia trichosantha* Fisch, and *Juniperus foetidissima* Wild., while the ungrazed areas are characterized by *Avena sterilis* L., *Calepina irregularis* (Asso) Thell., *Capsella bursa-pastoris* (L.) Medik., *Hordeum vulgare* L., *Taraxacum officinale* (L.) Weber ex F.H.Wigg., and *Urtica dioica* L.

diagnostic species. Diagnostic species of tree cutting areas are *Cerasus mahaleb* (L.) Miller var. *mahaleb* (L.) Miller, *Cistus creticus* L., *Colutea arborescens* L, *Cruciata taurica* (Pallas ex Willd.) Ehrend, *Jasminum fruticans* L., *Pistacia terebinthus* L. subsp. *palaestina* (Boiss.) Engler, *Polygala pruinosa* Boiss. subsp. *pruinosa* Boiss., and *Vicia narbonensis* L., while uncutted areas are characterized by *Amelanchier rotundifolia* (Lam). Dum.-Courset, *Arbutus andrachne* L., *Globularia trichosantha* Fisch, *Juniperus oxycedrus* L. subsp. *oxycedrus*, *Phillyrea latifolia* L., *Quercus hartwissiana* Steven, and *Q. petraea* (Mattuschka) Liebl. diagnostic species (Fig. 2).

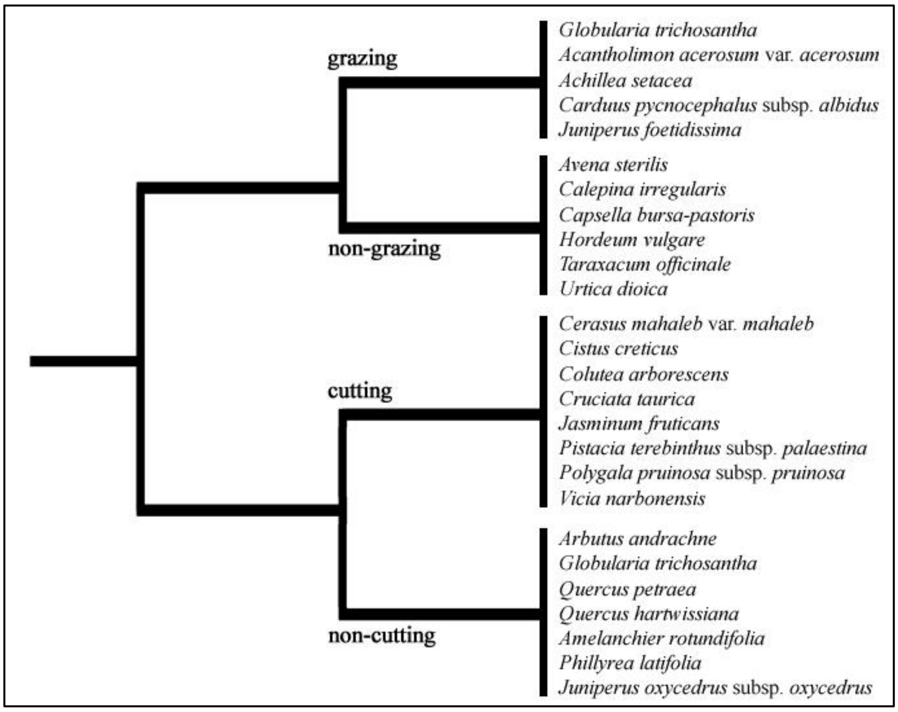

Figure 2. Plant communities considering disturbance factors in the study area resulting from the TWINSPAN analysis.

Detrended correspondence analysis (DCA) diagram showed the existence of the gradient considering the first axis (Eigenvalue of axis 1 is 0.96). It is an elevation gradient. Plant communities have spread depending on the elevation. Plant communities in non-grazing and non-cutting areas grouped at the left of ordination plot, whereas plant communities in cutting and grazing areas grouped at the right of the ordination plot (Fig. 3).

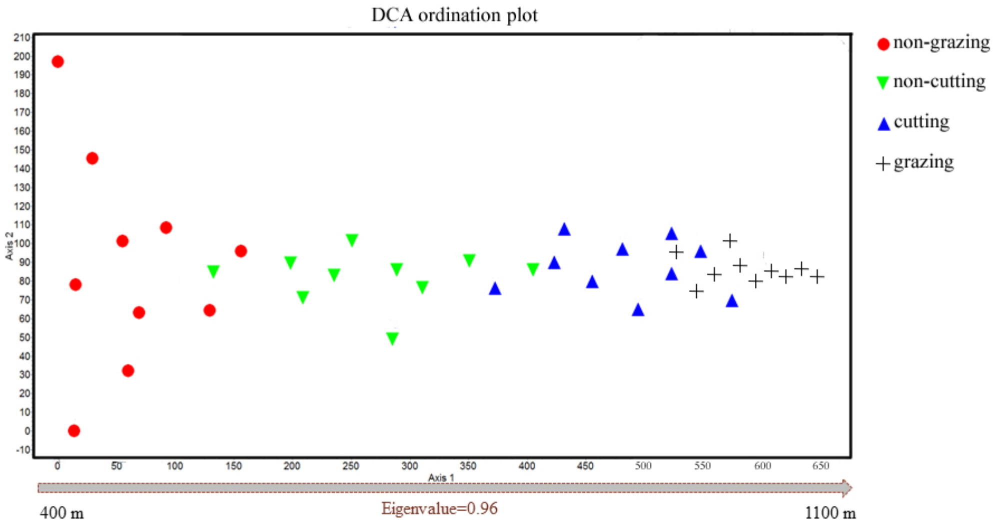

Figure 3. Result of the detrended correspondence analysis (DCA) withthe ordination diagram showing plant communities' position.

The first two axes explained 81.79 % total variance of the Principal Component Analysis (PCA). PCA revealed that pH, soil nitrogen content (%), soil water content were found to be significant in axis 1, while light availability was found to be significant in axis 2. Soil nitrogen (%) and soil water content were negative in axis 1, while soil pH and light availability were positive in axis 1 and 2, respectively (Table 1).

Light availability was positively correlated with plant communities in cutting areas, While soil nitrogen content and water content were negatively correlated plant communities in grazing areas. pH was positively correlated with plant communities in non-grazing areas (Fig. 4).

Table 1. Eigenvalues for studied environmental factors (Significant values were marked in bold).

	Axis 1	Axis 2
Soil pH	**0.508**	-0.266
Soil nitrogen content (%)	**-0.568**	-0.450
Soil moisture	**-0.646**	0.229
Light availability	0.033	**0.820**

Species diversity indices (H and J) were high in non-cutting and non-grazing plant communities compared to the other areas. Beta diversity was high in cutting and grazing plant communities as compared to the other areas. Statistically significant differences were found among the beta diversities with respect to plant communities (Table 2).

4. Discussions

The effects of environmental and disturbance factors on plant communities in terrestrial ecosystems are significant (Davies et al., 2007; Pausas and Austin, 2001). These factors affect the establishment, growth and reproduction of species (Pierce et al., 2007; Duru et al., 2010; Frenette-Dussault et al., 2012). According to TWINSPAN and DCA analysis, we found the main four plant communities: grazing, cutting, non-cutting and non-grazing. These communities are distributed according to altitude. Because topographic factors (altitude, geographical aspect, and slope) are primary factors of vegetation distribution (Mark et al., 2000) and affecting plant diversity (Vujnovic et al., 2002).

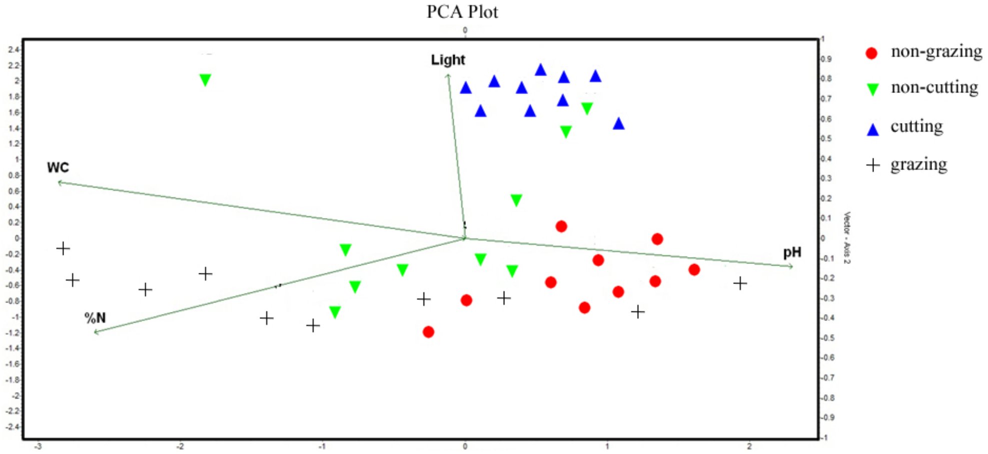

Figure 4. PCA analysis of the among environmental factors and plant communities.

PCA analysis showed that pH, soil nitrogen content (%), soil water content and pH were determining factors of vegetation distribution. In the cutting area, light availability is the main determining factor on species composition, while in the non-cutting area, soil pH and nitrogen content are determining factors (Chai et al., 2016; Tardella et al., 2016). Additionally, unpalatable and thorny species are dominant in grazing vegetation, and fast-growing species are dominant in non-grazing vegetation (Tardella et al., 2016; Kılıç et al., 2018).

Table 2. Diversity indices of plant communities (Different lowercase letters indicate significant differences)

	Grazing	Non cutting	Non grazing	Cutting	*Sig.*
Shannon–Wienner H indice	0.882±0.024**a**	0.973±0.012**a**	0.921±0.008**a**	0.890±0.011**a**	0.352**ns**
Shannon J indice	1.016±0.031**a**	1.062±0.027**a**	1.229±0.019**a**	1.235±0.009**a**	0.244**ns**
β indice	3.481±0.240**c**	0.367±0.004**a**	0.215±0.003**a**	1.137±0.021**b**	0.022*

Overgrazing in meadows and pastures damages the ground flora and prevents the regeneration of dominant species (Malik et al., 2016). However, Pettit et al. (1995) stated that overgrazing increases the proportion of unrelated species.

When evaluated results obtained, Shannon-Wienner diversity indexes of grazing vegetation were lower than the other vegetation types (Zhao et al., 2007; García et al., 2009; Tälle et al., 2016; Faria et al., 2018).

It has been found that grazing has a significant effect on species richness and diversity and that the number of species and diversity indexes are lower in these areas (Lu et al., 2017; Tälle et al., 2016). Besides, it has been shown that overgrazing negatively affects bush and tree species and thus decreases species richness (Roder et al., 2002; Kumar and Shahabuddin, 2005).

In cutting vegetation, light availability is the main factor (Tardella et al., 2016). Cutting causes permanent grazing gaps, and grassland species are recolonized (Dzwonko and Loster, 1998). These areas are called wood-pastures. If regeneration fails, wood-pastures become permanent. (Bergmeier et al., 2010). In non-cutting vegetation, canopy species have an excellent availability to take light as compared to subcanopy species. Besides, soil pH and nitrogen content affect ground flora formations (Augusto et al., 2003; Chai et al., 2016).

Species diversity indices (H and J) were high in non-cutting vegetation compared to the cutting vegetation. The ground flora diversity and composition is influenced by the species composition of the canopy species (Barbier et al., 2008; Gilliam, 2007; Hunter, 1999). Beta diversity was higher in cutting and grazing plant communities than the other plant communities.

Overgrazing harms the ground flora in meadows and pastures, preventing the regeneration of dominant species (Malik et al., 2016). Also, the disappearance of shrub and tree species causes the species richness to decrease gradually (Roder et al., 2002; Kumar and Shahabuddin, 2005). Considering the results obtained, it was consistent with previous studies (Faria et al., 2018). Tree cutting and forestry studies increase habitat heterogeneity (Bergmeier et al., 2010).

Paying attention to the protection of biological diversity in forestry activities should be the main goal of sustainable forest management. In this study, we revealed that disturbance and environmental factors affect vegetation types and species composition.

Conflict of Interest

Authors have declared no conflict of interest.

Authors' Contributions

The authors contributed equally.

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