

Effects of Grazing Intensity on the Regeneration of Woody Species in an Oak Woodland

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Abstract

In the Mediterranean regions, oak forests are commonly used for livestock grazing. However, it is well documented that livestock grazing is an essential factor that can affect the success of natural regeneration of oak and other woody species of the understorey. Consequently, it influences the composition and structure of oak woodlands. The main objective of the present study was to examine the effects of grazing intensity on characteristics of oak seedlings establishment (density, height, number of leaves) and on the diversity of the woody species seedlings. The research was conducted in open canopy *Quercus frainetto* woodland, grazed by a herd of 500 goats for eight months per year, located in Evros region, north-eastern Greece. The distance from a goat corral was used to represent relative grazing intensity. In May 2016, vegetation measurements were made along transects placed at 50, 150, 300, 600 and 1200 m from the goat corral, running perpendicular to four replicates. According to the results, increased grazing intensity significantly reduced the density, the plant height and the number of leaves of *Quercus frainetto* seedlings. Grazing intensity did not affect significantly diversity, evenness and dominance indices for the woody species seedlings. However, heavy grazing reduced species richness and the Chao1 index.

Keywords: goat grazing, *Quercus frainetto*, seedlings establishment, silvopastoral system, species diversity

Introduction

It is well substantiated that oak woodlands have essential ecological and socioeconomic importance in the Mediterranean region (López-Sánchez *et al.*, 2014). They are among the major components of biodiversity hot spots (Eichhorn *et al.*, 2006), while they support rural population by providing a variety of wood products and forage for livestock (Lopez-Sanchez *et al.*, 2014). Oak woodlands and shrublands comprise the most widespread vegetation type in Greece. Deciduous oaks cover approximately 23% of the country's high forest (1.5 million ha) and specific oak woods are traditionally used for livestock grazing (Anonymous, 1992; Koutsidou *et al.*, 2008; Manousidis *et al.*, 2016a).

Woodland grazing is an important part of the European cultural and ecological heritage (Hartel and Plieninger, 2014). Although traditional forest grazing has been reduced in many parts of Europe, it is still practiced in the Mediterranean region (Humphrey *et al.*, 1998) as small ruminants are able to profit from this type of vegetation (Varela and Robles-Cruz, 2016). Oak woodlands and

shrublands are important forage sources especially for goats as they prefer woody species more than herbaceous ones and their diet consists mainly of lignified species (Manousidis *et al.*, 2016b).

Grazing in woodlands has been debated in Europe and elsewhere as grazing herbivores are considered to pose a serious threat on the biodiversity, regenerative capability of woody species and economic value of multi-purpose forests. Plieninger (2007) reported that livestock grazing has enhanced biodiversity and reduced wild fire risk, but may endanger the long-term stability of woodland ecosystems. Grazing includes not only defoliation by animals, but it is also associated with disturbances such as animal trampling, soil compaction and mineralization by deposition of urine and feces (Alados *et al.*, 2004) which in turn determines the patterns of vegetation in the Mediterranean ecosystems (Carmel and Kadmon, 1999). Forest grazing has been reported to cause tree damage through trampling and browsing (Mayer *et al.*, 2006; Vandenberghe *et al.*, 2007) and loss of species richness and diversity (Fleischner, 1994). Moreover, forest grazing is widely considered as negative to natural regeneration of broadleaved tree species in particular

(Van Ijssel, 1990). However, there are findings suggesting that despite livestock impacts to some saplings, damage levels were insufficient to alter tree regeneration (Buffum *et al.*, 2009; Kaufmann *et al.*, 2014). McCreary and George (2005) reported that the presence or absence of livestock was not sufficient to explain the pattern of oak regeneration. Forest grazing can enhance tree growth by reducing the biomass of herbaceous and shrubby vegetation that outcompete tree seedlings (Darabant *et al.*, 2007). Grazing has also been reported to promote biodiversity (Mountford and Peterken, 2003; Mosquera-Losada *et al.*, 2009). Lempesi *et al.* (2013) results in a grazed oak woodland in northern Greece confirmed the moderate grazing hypothesis (Noy Meyer, 1995; Tilman, 1997) that light and moderate grazing results in an increase of biodiversity. Thus, managed woodland grazing systems are increasingly recognised as being beneficial to woodland biodiversity (McEvoy *et al.*, 2005).

It is well documented that the effects of livestock grazing on the vegetation of the Mediterranean ecosystems are dependent on grazing intensity (Milchunas and Lauenroth, 1993; Montalvo *et al.*, 1993; Osem *et al.*, 2002). Thus, the objective of the present study was to examine the effects of grazing intensity on the characteristics of oak seedlings establishment (density, height, number of leaves) and on the diversity of the woody species seedlings.

Materials and Methods

The research was conducted in the area of Pentalofos, which is located in Evros region, NE Greece (Fig. 1). The oak forest of Pentalofos occupies a total area of 10200 ha. It is mainly used by the local population for firewood production and for livestock grazing. Several species of deciduous oaks consist the forest canopy comprising *Quercus frainetto*, which is dominant, while other species such as *Q. petraea*, *Q. pubescens* and *Q. cerris* are less common. Other woody species, more or less frequently found, include *Carpinus orientalis*, *Fraxinus ornus*, *Juniperus oxycedrus*, *Cornus mas*, *Tilia tomentosa*, *Phillyrea latifolia* and *Acer monspessulanum*. The climate of the area is classified as sub-Mediterranean, with cold, moist winters and warm, dry summers. The average maximum temperature is 30.5 °C in July and the average minimum temperature is -7.0 °C in January. The mean annual precipitation is 539.5 mm. The study area is grazed mainly by a herd of 500 Greek local breed goats for eight months per year.

The distance from a goat corral was used to represent relative grazing intensity. In May 2016, vegetation measurements were taken within quadrats of 1 m² that placed along transects of 20 m long. The transects were placed at 50, 150, 300, 600 and 1200 m from the goat corral, running perpendicular to four replicates. These distances stand for very heavy, heavy, moderate, light and very light grazing, respectively. The number of woody species, the density of oak seedlings, the height of each seedling and the number of leaves per seedling were measured in each quadrat. Additionally, species richness, species diversity, evenness and dominance were determined

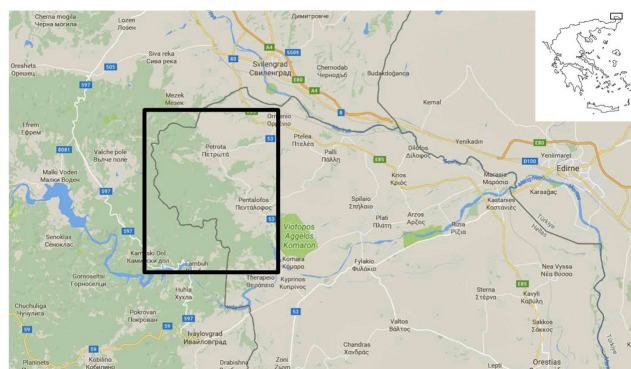


Fig. 1. Location map of study area

for the woody seedlings by the following indices: The Shannon-Wiener evenness index (E), the Simpson diversity index (C), the Chao1 index (S), and the Berger-Parker dominance index (D). The formulae of the indices are given below (Henderson, 2003):

$$E = H / \log_2 S$$

$$D = 1/C \text{ where } C = 1 - \sum_i p_i^2$$

$$d = N_{\max} / N_T$$

where S is the maximum recorded number of taxa, p_i is the proportional abundance of the i -th taxa, N_{\max} is the number of records of the dominant taxon and N_T is the total number of records.

$$S_{\text{Chao1}} = S_{\text{obs}} + n_1^2 / 2n_2$$

where S_{obs} is the number of observed species, n_1 is the number of singletons (species captured once), and n_2 is the number of doubletons (species captured twice). Floristic diversity indices were calculated using the PAST-Paleontological Statistics program (Hammer *et al.*, 2001).

One-way ANOVA was used to analyse the effect of grazing intensity on the characteristics of oak seedlings (density, height, number of leaves) and on the diversity indices of the woody species seedlings. The LSD at the 0.05 probability level was used to detect the differences among means (Steel and Torrie, 1980). The obtained data were analysed using the SPSS statistical software v. 17.0 (SPSS Inc. Chicago, IL, USA).

Data were subjected to simple linear regression analyses with the distance from the corral as the independent variable and the characteristics of oak seedlings (density, height, number of leaves) as the dependent variables. The choice of the best-fit equation was based on the coefficient of determination.

Results and Discussion

Deciduous woody species, and especially oak, are highly preferred by goats, and comprise a great proportion of their diet whenever they are available (Papachristou and Nastis, 1996; Manousidis *et al.*, 2016b). However, although grazing removes leaf tissue, in most cases, it will not harm the growing point that produces the leaves (Trlica, 1999). Grazing intensity significantly affected oak seedlings density, their height and the number of leaves (Table 1). Oak seedling density and the number of leaves per seedling

were significantly higher under very light grazing, while height was significantly increased under light grazing intensity followed by the very light one. Generally the values of all the measured characteristics of oak seedlings were decreased as grazing intensity increased. Regression analyses (Table 2) revealed a significant linear relationship between grazing intensity and seedling density ($R^2=0.96$) and the number of leaves per oak seedling ($R^2=0.81$). However, coefficient of determination was lower ($R^2=0.47$) for seedling height, indicated that the variation in this trait could be explained by other factors besides grazing intensity. The results of the present study are suggesting that survival and growth of *Quercus* seedlings in heavily grazed areas are significantly limited. These results are in agreement with those of Carmona *et al.* (2013) who observed an important effect of grazing regime on the height of oak juveniles. Additionally, Al-Rowaily *et al.* (2015) found that livestock exclusion significantly increased density of shrubs and trees. Moreover, Smit *et al.* (2006) reported that livestock grazing can directly destroys seeds and seedlings, thus reducing natural regeneration. Browsing of oak seems to be an essential factor driving regeneration rate, although other environmental factors have been reported to be important too (López-Sánchez *et al.*, 2014). Moreover, long-term heavy grazing can indirectly affects oak recruitment by increasing soil compaction and reducing organic matter (Welker and Menke, 1987).

Overall, seedlings of eight woody plant species were recorded. Grazing intensity did not affect significantly Simpson diversity index (C), Shannon-Wiener evenness index (E) and Berger Parker dominance index (D), of the

woody seedlings (Table 3). Significantly lower N (Number of species) and Chao1 index (S) was recorded at the distances close to the goat corral (Table 3). The Chao1 estimate richness by adding a correction factor to the observed number of species (Hughes *et al.*, 2001).

Grazing is a major factor controlling species composition and diversity (McNaughton, 1983; Ren *et al.*, 2012). Alados *et al.* (2004) found that the number of species declined significantly with grazing pressure. In contrast, Pizzio *et al.* (2016) reported that the range of stocking rates had no effect on species richness, but reduced diversity through the effect on evenness. These differentiated results can be attributed to the different type of ecosystem and to different type of grazer. Lempesi *et al.* (2013) found that goats browsing affected species diversity of the woody vegetation layer but had minimum impact on the herbaceous vegetation layer.

Species richness can serve as a comprehensible index of community structure (Gotelli and Colwell, 2010). Vrahnakis *et al.* (2014) have reported that plant diversity of valonia oak silvopastoral woodlands is determined mostly by management factors such as grazing intensity. Grazing in oak woodlands can combat shrub encroachment which is negatively correlated with plant species richness and diversity of such ecosystems in the Mediterranean region (Alados *et al.*, 2004). The results of the present study indicated that moderate grazing can control woody species expansion in oak woodland, fact that can benefit the function of this ecosystem and promotes some of the ecosystem services provided.

Table 1. Effect of goat grazing intensity on seedling density, seedling height and number of leaves per *Quercus frainetto* seedling

Distance from the corral (m)	D - seedling density (no plants/m ²)	H - seedling height (cm)	Number of leaves / seedling
50	6.2 b	4.8 bc	2.1 b
150	4.5 b	10.5 ab	4.9 b
300	2.5b	8.7 b	4.0 b
600	15.7 ab	19.7 a	4.1 b
1200	30.0 a	15.2 ab	9.8 a
LSD _{0.05}	17.6	9.4	3.93

Note: Means in the same column followed by the same letter are not significantly different (LSD test, $P \leq 0.05$)

Table 2. Prediction models for seedling density, seedling height and number of leaves per *Quercus frainetto* seedling as a function of the goat grazing intensity

Oak characteristics	Simple linear regression equation	R ²
Seedling density	0.0266X - 1.7826	0.96
Seedling height	0.0086X + 7.8128	0.47
Number of leaves per seedling	0.0056X + 2.4004	0.81

Note: Independent variable (X) = distance from the goat corral

Table 3. Number of species (N), Simpson diversity index (C), Shannon-Wiener evenness index (E), Berger Parker dominance index (D) and Chao1 (S) for the woody seedlings at the different distances from the goat corral

Distance from the corral (m)	N	C	E	D	S
50	1.25 bc	1.00 a	0.67 a	0.64 a	1.25 ab
150	0.75 c	0.75 a	0.75 a	0.75 a	0.75 b
300	1.50 abc	1.38 a	0.96 a	0.84 a	1.50 ab
600	2.00 ab	1.42 a	0.80 a	0.85 a	2.25 a
1200	2.25 a	1.39 a	0.72 a	0.83 a	2.25 a
LSD _{0.05}	0.89	NS	NS	NS	1.23

Note: Means in the same column followed by the same letter are not significantly different (LSD test, $P \leq 0.05$)

Conclusions

Increased grazing intensity significantly reduced oak seedling density, their height and the number of leaves per seedling. These results strongly suggest that heavy goat grazing significantly reduced the regeneration success and survival of oak seedlings. However, goats controlled other woody species encroachment as indicated by the reduced number of species recorded under high grazing intensity, fact that may enhance biodiversity and benefits a number of ecosystem services. Sustainable grazing management practices have to be applied in order to maintain Mediterranean oak woodlands.

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