AcademicPres

Available online at www.notulaebotanicae.ro

Print ISSN 0255-965X; Electronic 1842-4309

Not Bot Horti Agrobo, 2013, 41(2):567-575

Notulae Botanicae Horti Agrobotanici Cluj-Napoca

Soil Properties and Plant Community Changes along a Goat Grazing Intensity Gradient in an Open Canopy Oak Forest

Aimilia LEMPESI, Apostolos P. KYRIAZOPOULOS*, Michail ORFANOUDAKIS, Georgios KORAKIS

*Democritus University of Thrace, Department of Forestry and Management of the Environment and Natural Resources, 193 Pantazidou str., 68200 Orestiada, Greece; apkyriaz@fmenr.duth.gr (*corresponding author)*

Abstract

Understanding how the management practices of silvopastoral systems affect the long-term sustainability of oak ecosystems and what their influence is on nutrient cycling and plant community, is of great interest. The aim of this study was to examine the effects of relative grazing intensity on soil properties and on vegetation characteristics in an open canopy oak forest dominated by *Quercus frainetto*. The research was conducted in the area of Pentalofos, which is located in Evros region, north-eastern Greece and is grazed by goats. The distance from a goat corral was used to represent relative grazing intensity. In June 2011, soil and vegetation samples were collected along transects placed at 50, 150, 300, 600 and 1200 m from the goat corral, running perpendicular to three replicates. Soil measurements included pH, phosphorous (P) and nitrogen (N) concentrations while vegetation measurements included plant cover, species composition and diversity. Plant cover was not significantly different among grazing intensities. Species diversity, especially of the woody vegetation layer, was significantly higher in the light grazing intensity in comparison to both the heavy and the very light grazing. Heavy grazing reduced soil organic matter while it increased total nitrogen. Grazing intensity did not affect available P and soil pH. Light to moderate goat grazing could ameliorate floristic diversity and increase sustainability of oak forests in the Mediterranean region.

Keywords: herbaceous layer, silvopastoral system, shrubs, species diversity

Introduction

The Mediterranean basin is a global biodiversity hotspot with a high degree of species richness (Myers *et al*., 2000), fact strongly related to the management practices applied continuously for more than 10,000 years, including grazing (Bergmeier and Dimopoulos, 2004; Kyriazopoulos, 2012; Noy-Meir, 1995). The positive effects of grazing in ecosystems highlight the importance of traditional extensive livestock farming practices as an ecological tool for the maintenance or even the restoration of these ecosystems (Papanastasis, 2009). Furthermore, livestock grazing is considered essential to maintaining species diversity, as indicated from many communities where species diversity decreased when grazing was excluded (Noy-Meir *et al*., 1989). On the contrary, livestock overgrazing can cause negative long-term effects on the composition, structure and dynamics of vegetation (Anderson *et al*., 2010; Liang *et al*., 2009), and on biodiversity (Oba *et al*., 2008; Spottiswoode *et al*., 2009).

It is well documented that in the Mediterranean ecosystems the effects of livestock grazing on vegetation composition depend on the grazing intensity (Milchunas and Lauenroth, 1993; Montalvo *et al*., 1993; Osem *et al*., 2002). Generally, when moderate grazing intensity is applied, plant diversity tends to increase as dominant species are reduced while the less competitive ones are increased (Milchunas *et al*., 1988). Additionally, Catorci *et al*. (2012) supported that different grazer types in the same environment could lead to floristic differentiation of the plant community as they exert selective pressure on plant species, related to their browsing strategies and foraging behaviour (Dumont *et al*., 1995; Grant *et al*., 1996).

Livestock grazing primarily affects soil properties by direct impacts through trampling and lunging and indirectly by altering plant community structure (Beukes and Cowling, 2003). Soil chemical characteristics as well as soil moisture are the most important soil properties that may be altered by livestock grazing (Al-Seekh *et al*., 2009). Numerous studies have shown that overgrazing causes heavy destruction in soil structure and compaction, leading to a decrease in soil organic C and N contents (Shi *et al*., 2010). Moreover, Pei *et al*. (2008) supported that modifications in nutrient cycling due to heavy grazing led to permanent degradation of productivity and to a possible destruction of the ecosystem. Vegetation degradation leads to the exposure of the soil surface to direct wind and water erosion. As a result, the fertile top soil and its content of nutrients are lost (Kumbasli *et al*., 2010). On the contrary, sustainable grazing management ameliorates litter accumulation thus resulting in the reduction of soil erosion, the increase of permeability and water holding capacity of the soil, and to the adjustment of soil surface temperature (Fakhimi *et al*., 2011).

Oak forests in the Mediterranean region are rich in plant species and are of great ecological and economic interest (LeHouerou, 1981). Traditionally, these forests maintain prominent area providing firewood, charcoal and forage for livestock (Debussche *et al*., 2001). Deciduous oak forests, especially the open coppice, have been affected more than other forest types by livestock grazing as silvopastoralism is well adapted to the Mediterranean environment (Papanastasis *et al*., 2009; Robles *et al*., 2007). This traditional silvopastoral management of oak forests may increase forage yield and nutritive value (Moreno, 2008; Papanastasis, 1986), reduce wildfire risk (Nair *et al*., 2008) and enhance biodiversity (Mosquera-Losada *et al*., 2009). Consequently, there is evidence that coexistence of livestock and forest production can be achieved (Ainalis *et al*., 2010).

Grazing effects in species composition and in species diversity are not the same for all vegetation types (Gonzalez-Hernandez and Silva-Pando, 1996; Onaindia *et al*., 2004). Similarly, grazing effects on soil properties may vary among ecosystems, as in the case of forests where tree litter is only slightly affected by herbivores (Smit and Kooijman, 2001). The effects of grazing on species composition, floristic diversity and soil properties have been investigated in different ecosystems (Suominen and Danell, 2007; Singer and Schoenecker, 2003; van Wieren and Bakker, 2008; Zhou *et al*., 2006). Surprisingly, limited information is available on the effects of grazing on oak forests in the Mediterranean region although grazing is considered as a prominent ecological and evolutionary driving force (Perevolotsky and Seligman, 1998). Therefore, the main objective of the present study was to examine the effects of goat relative grazing intensity on species composition, floristic diversity and some soil properties in an open canopy oak forest dominated by *Quercus frainetto* Tan.

Materials and methods

The research was conducted in the area of Pentalofos, which is located in Evros region, NE Greece. The oak forest of Pentalofos occupies a total area of 10199.56 ha. It is mainly used for firewood and livestock grazing by the local population. The dominant oak species is *Quercus frainetto*, while other common oak species are *Quercus petraea*, *Quercus pubescens* and *Quercus cerris*. The spread of oak covers almost the entire area of the forest. Other common woody species 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 has been communally grazed by 500 goats for 7 months per year, for a long period of time.

As was the case with previous studies (Landsberg *et al*., 2003; Sasaki *et al*., 2008, 2012; Todd, 2006) where a grazing gradient approach (Andrew, 1988) was applied, the distance (in meters) from a goat corral was used to represent relative grazing intensity in this study. Vegetation sampling was performed along 20 m-long transects placed at 50, 150, 300, 600 and 1200 m from the goat corral, running perpendicular to three replicates, in June 2011. The distances from the goat corral stand for very heavy, heavy, moderate, light and very light grazing respectively. The plant cover and the floristic composition were measured by using the line-point method (Cook and Stubbendieck, 1986). The abundance of a species was estimated by the frequency of its occurrence at 0.20 m intervals along each transect (100 contacts per transect). The vegetation sampling was conducted at the peak of the flowering season, i.e. early June, so as to ensure the presence of the entire range of the plant community life-forms. The nomenclature of the recorded plant taxa follows Strid and Tan (1997-2002) and Tutin *et al*. (1968-1980; 1993).

Floristic diversity, evenness and dominance were determined for the total vegetation data and for the woody and herbaceous layers separately by the following indices: Species Richness (N), the Shannon-Wiener diversity index (H'), the Shannon-Wiener evenness index (E), the Simpson diversity index (C) and the Berger-Parker dominance index (D). The formulae of the indices are given below (Henderson, 2003):
where S is the maximum recorded number of taxa, pi 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

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

$$E = \frac{H}{\log_2 S}$$

$$D = \frac{1}{C}, \text{ where } \quad C = 1 - \sum_{i}^{S_{obs}} p_i^{2}$$

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

total number of records.

Soil samples were collected within each of three quadrats along the transects. Samples collected from the 0-10 cm soil layers were air dried and sieved through 2 mm and 210 μm meshes. Soil organic matter was determined by means of wet oxidation (Nelson and Sommers, 1982). Total N was determined by the Kjeldahl method (Stevenson, 1982). Available P was extracted with 0.5N $NaHCO_3$ at pH 8.5 and was measured spectophotometrically by a modified phosphomolybdenum blue method (Alifragis, 2010). Soil pH was determined by using a glass electrode. The obtained data were analysed with SPSS 17 for Windows. One-way ANOVA was used to analyse the effect of grazing intensity on vegetation cover, functional groups composition, diversity indices and soil properties. The LSD at the 0.05 probability level was used to detect the differences among means (Steel and Torrie, 1980).

Results and discussion

Total vegetation cover was not affected significantly by grazing intensity (Fig. 1). This could be attributed to the dominance of fewer but larger plants in the heavily grazed plots. Liu *et al*. (2006) have also reported similar results of total vegetation cover not having been reduced under heavy grazing in comparison to moderate or light grazing, unlike other studies (Hill *et al*., 1992; Pluhar *et al*., 1987).

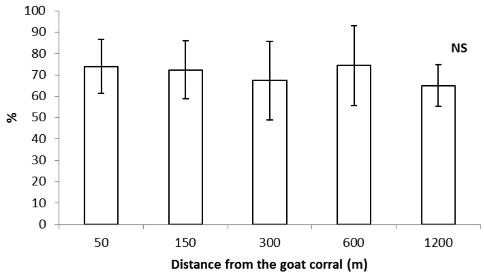

Fig. 1. Plant cover (mean ± S.E.) at the different distances from the goat corral (NS, Not Significant)

Different grazing intensity did not significantly alter species composition (Appendix: Tab. 1). Woody species were dominant under all grazing intensities. Although it has been reported that protection from grazing or very light grazing usually leads to woody species increase (Petit *et al*., 1995), this was not the case for the present study. The highest percentage of grasses was found in the moderate grazing intensity and then in the very light one, while their contribution to vegetation composition decreased when heavy grazing occurred, but this reduction did not produce significant results.

Legumes had limited contribution under all grazing intensities. This could be related to the fact that legume species are not shade tolerant in general and usually reduced under shaded conditions (Kyriazopoulos *et al*., 2006). It has to be further noted that unpalatable species such as *Carex flacca* increased under heavy grazing while palatable ones like *Dactylis glomerata* decreased. Zhou *et al*. (2006) reported similar trends for the response of palatable and unpalatable species under heavy grazing. The non-significant changes of species composition under different grazing intensities could be attributed to the productive environment and rich species resource in the study area.

Grazing intensity did not affect significantly Species richness (N), Shannon-Wiener diversity index (H) and Shannon-Wiener evenness index (E) for the total vegetation data (Tab. 1). Floristic biodiversity, as described by Simpson index (C) was significantly higher under light grazing intensity and tended to decrease as grazing intensity increased. Dominance as described by Berger-Parker index followed the opposite tend. Heavy grazing leads to the dominance of few grazing tolerant or unpalatable species fact with negative effects on floristic diversity (Noy Meir and Walker, 1986). It has to be noted that under very light grazing (1200 m from the goat corral) Simpson diversity index reduced due to the dominance of few competitive species (Willoughby and Alexander, 2007). Many authors have reported that grazing abandonment leads to a decrease in plant species richness (Guretzky *et al*., 2007; Poschlod *et al*., 2005).

The analysis of diversity, evenness and dominance indices was done separately for the woody and the herbaceous layers and led to some interesting findings. Grazing intensity affected all the indices for the woody vegetation layer (Tab. 2), while it did not affect significantly any index for the herbaceous vegetation layer (Tab. 3). Goats as browsers (Perevolotsky *et al*., 1998) affected woody vegetation apparently, while their grazing activity on herbaceous vegetation was limited and did not produce any significant impacts. Very heavy grazing resulted in a significant reduction of floristic diversity and evenness and to a significant increase of Berger Parker dominance index in the woody vegetation layer. This result confirms many previous studies supporting that under heavy grazing biodiversity decreases (Louhaichi *et al*., 2009; Noy Meyer, 1995) due to the dominance of certain species. These species are favoured by grazing and as a result their abundance and cover increases, while others are not and reduce in number and cover (Belsky, 1992). All the tested diversity and evenness indices of the woody layer vegetation reached their maximum values under light grazing intensity (600 m from the goat corral). Additionally, dominance was significantly reduced under this grazing intensity. However, Simpson diversity index was significantly reduced and Berger Parker

Tab. 1. Species richness (N), Shannon-Wiener diversity index (H), Shannon-Wiener evenness index (E), Simpson diversity index (C) and Berger Parker dominance index (D) for the total vegetation (mean ± S.E.) at the different distances from the goat corral

Distance (m)	N	H	E	C	D
50	16.3±2.3 [a]	2.07±0.29 [a]	0.47±0.06 [a]	6.21±0.62 [c]	0.39±0.03 [a]
150	15.3±2.2 [a]	2.11±0.29 [a]	0.48±0.07 [a]	7.20±0.40 [bc]	0.34±0.01 [ab]
300	16.7±4.9 [a]	2.25±0.26 [a]	0.51±0.06 [a]	8.41±0.44 [b]	0.28±0.02 [bc]
600	17.7±3.5 [a]	2.32±0.28 [a]	0.52±0.06 [a]	9.67±0.43 [a]	0.27±0.02 [c]
1200	16.7±1.8 [a]	2.34±0.05 [a]	0.53±0.01 [a]	7.84±0.46 [b]	0.29±0.02 [bc]

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

Tab. 2. Species richness (N), Shannon-Wiener diversity index (H), Shannon-Wiener evenness index (E), Simpson diversity index (C) and Berger Parker dominance index (D) for the herbaceous vegetation layer (mean ± S.E.) at the different distances from the goat corral

Distance (m)	N	H	E	C	D
50	11.0±2.3 a	1.97±0.21 a	0.49±0.05 a	6.76±1.48 a	0.33±0.07 a
150	08.3±1.5 a	1.77±0.32 a	0.44±0.08 a	6.51±2.20 a	0.38±0.13 a
300	11.3±3.8 a	1.95±0.36 a	0.48±0.09 a	6.71±1.81 a	0.35±0.08 a
600	11.0±1.7 a	2.08±0.17 a	0.52±0.04 a	7.78±1.69 a	0.32±0.06 a
1200	10.0±0.6 a	1.89±0.05 a	0.47±0.01 a	5.49±0.43 a	0.35±0.04 a

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

Tab. 3. Species richness (N), Shannon-Wiener diversity index (H), Shannon-Wiener evenness index (E), Simpson diversity index (C) and Berger Parker dominance index (D) for the woody vegetation layer (mean ± S.E.) at the different distances from the goat corral

Distance (m)	N	H	E	C	D
50	5.3±0.3 a	1.07±0.05 c	0.32±0.02 c	2.53±0.04 c	0.62±0.01 a
150	7.3±1.5 a	1.37±0.12 ab	0.42±0.01 ab	3.69±0.32 b	0.49±0.03 b
300	5.3±1.2 a	1.26±0.09 bc	0.38±0.01 b	3.17±0.28 b	0.50±0.03 b
600	6.7±1.8 a	1.51±0.09 a	0.45±0.01 a	4.85±0.36 a	0.41±0.01 c
1200	6.7±1.5 a	1.48±0.11 a	0.44±0.04 a	3.57±0.23 b	0.48±0.03 b

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

Tab. 4. Soil properties (mean ± S.E.) at the different distances from the goat corral

Distance (m)	Organic matter (%)	N (%)	P ($mg^{*}100g^{-1}$)	pH
50	0.511±0.143 c	0.143±0.020 a	2.063±0.221 a	6.206±0.049 a
150	0.704±0.097 bc	0.109±0.006 b	2.203±0.296 a	6.268±0.127 a
300	0.874±0.055 ab	0.065±0.006 c	2.435±0.156 a	6.207±0.157 a
600	1.070±0.043 a	0.068±0.001 c	2.229±0.361 a	6.468±0.322 a
1200	1.126±0.070 a	0.091±0.007 bc	2.149±0.168 a	6.429±0.262 a

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

dominance index was significantly increased under very light grazing intensity (1200 m from the goat corral). This fact confirms the moderate grazing hypothesis (Hobbs and Huenneke, 1992; Noy Meyer, 1995; Tilman, 1997) that light and moderate grazing results in an increase of biodiversity, whereas at low grazing pressures or at absence of grazing some species become dominant, hence the reduced diversity (Willoughby and Alexander, 2007).

Significant lower organic matter content was obtained at the distances close to the goat corral indicating that organic matter decreased gradually as grazing intensity increased (Tab. 4). This decrease can be attributed to a significant reduction in litter due to vegetation removal by grazing livestock (Xie and Witting, 2004). However, moderate and light grazing did not affect significantly soil organic matter. On the contrary, total nitrogen was significantly higher at the closest distance to the goat corral (Tab. 4). The higher amount of nitrogen in soil under heavy grazing is probably caused by animal excrement and urine (Tamartash *et al*., 2007). This result is in agreement with this that has reported by Liu *et al*. (2011). Grazing intensity did not significantly affect available P and soil pH (Tab. 4). Milchunas and Lauenroth (1993) analysed a set of data from 236 sites around the world and found no relationship between grazing and soil phosphorus and pH. Controversially, while Xie and Witting (2004) reported a significant reduction of available P under heavy grazing in a steppe rangeland, Dahlgren *et al*. (1997) found higher available P in oak woodland under grazing. Possibly, available P in soil is related to grazing and also to vegetation type.

Sustainable management of oak forests in the Mediterranean basin should take into account the positive effects of light and moderate goat grazing on floristic diversity, especially on the woody vegetation layer of the understorey. As moderate and light goat grazing did not alter soil properties and might cause only limited damages to oak regeneration (Plieninger *et al*., 2011), it can be proposed as the most appropriate grazing intensities for these ecosystems (Arevalo *et al*., 2011). Furthermore, since light to moderate goat grazing can control woody vegetation encroachment in the understorey of the Mediterranean oak forests it may be used as a tool to reduce the risk of wild fires (Papanastasis, 1986).

Conclusions – Management Implications

Heavy grazing of goats reduced floristic diversity and soil organic matter while it increased dominance of unpalatable woody species and total nitrogen. On the other hand, grazing intensity did not affect plant cover, available P and soil pH. Light to moderate goat grazing increased floristic diversity and had a minimal effect upon the analysed soil properties. Consequently, extensive moderate grazing can be a viable way of managing ecosystem sustainability of oak forests in the Mediterranean basin. To this purpose, livestock corrals need to be planned and organized and watering points need to be placed in such a way so as to enable sustainable oak forest management.

References

Ainalis AB, Platis PD, Meliadis IM (2010). Grazing effects on the sustainability of an oak coppice forest. For Ecol Manage 259:428-432.

Alifragis D (2010). Description, sampling, laboratory analyses of forest soils and plant tissues. Aivazis Press, Thessaloniki, Greece 181 p. (in Greek).

Al-Seekh SH, Mohammad AG, Amro YA (2009). Effect of Grazing on Soil Properties at Southern Part of West Bank Rangeland. Hebron Univ Res J 1:35-53.

Anderson PML, Hoffman MT, O'Farrell PJ (2010). Above ground perennial plant biomass across an altitudinal and land-use gradient in Namaqualand, South Africa. S Afr J Bot 76:471-481.

Andrew MH (1988). Grazing impact in relation to livestock watering points. Trends Ecol Evol 3:336-339.

Arévalo JR, Nascimento L, Fernández-Lugo S, Mata J, Bermejo L (2011). Grazing effects on species composition in different vegetation types (La Palma, Canary Islands). Acta Oecol 37:230-238.

Belsky AJ (1992). Effects of grazing, competition, disturbance and fire on species competition and diversity in grassland communities. J Veg Sci 3:187-200.

Bergmeier E, Dimopoulos P (2004). Wood pasture in an ancient submediterranean oak forest. Ecol Medit 30:5-14.

Beukes PC, Cowling RM (2003). Non-selective grazing impacts on soil-properties of the Nama Karoo. J Range Manage 56:547-552.

Catorci A, Gatti R, Cesare S (2012). Effect of sheep and horse grazing on species and functional composition of sub-Mediterranean grasslands. Appl Veg Sci 15(4):459-469.

Cook WC, Stubbendieck J (1986). Range research: Basic Problems and Techniques. Soc. Range Manage. Denver, Colorando, 317p.

Dahlgren RA, Singer MJ, Huang X (1997). Oak tree and grazing impacts on soil properties and nutrients in a California oak woodland. Biogeochemistry 39:45-64.

Debussche M, Debussche G, Lepart J (2001). Changes in the vegetation of *Quercus pubescens* after cessation of coppicing and grazing. Veg Sci 12:81-92.

Dumont B, D'hour P, Petit M (1995). The usefulness of grazing tests for studying the ability of sheep and cattle to exploit reproductive patches of pastures. Appl Anim Behav Sci 45:79-88.

Fakhimi E, Mesdaghi M, Dianati Tilaki GA, Tavan M (2011). Relationships among forage and litter production in three grazing intensities in Nodooshan Rangeland (Yazd, Iran). J Rangeland Sci 3:217-223.

González-Hernández MP, Silva-Pando FJ (1996). Grazing effects of ungulates of a Galician oak forest (northwest Spain). For Ecol Manage 88:65-70.

Grant SA, Torvell L, Sim EM, Small JL, Armstrong RH (1996). Controlled grazing studies on Nardus grassland: effects of between-tussock sward height and species of grazer on Nardus utilization and floristic composition in two fields in Scotland. J Appl Ecol 33:1053-1064.

Guretzky JA, Moore KJ, Burras CL, Brummer EC (2007). Plant species richness in relation to pasture position, management, and scale. Agric Ecosys Environ 122:387-391.

Henderson PA (2003). Practical Methods in Ecology. Blackwell Science Ltd., Oxford, UK, 300 p.

Hill MO, Evans DF, Bell SA (1992). Long term effects of excluding sheep from hill pastures in North Wales. J Ecol 80:1-13.

Hobbs RJ, Huenneke LF (1992). Disturbance, diversity, and invasion - implications for conservations. Conserv Biol 6:324-337.

Kumbasli M, Makineci E, Cakir M (2009). Long term effects of red deer (*Cervus elaphus*) grazing on soil in a breeding area. J Environ Biol 31:185-188.

Kyriazopoulos AP (2012). Research priorities for grassland science in the Eastern Mediterranean Region. Options Mediterr 102:523-526.

Kyriazopoulos AP, Fotiadis G, Nastis AS (2006). Shading effects of trees on the understorey species composition and floristic diversity. In: Papanastasis VP, Parissi ZM (Eds.). Range Science of xerothermic areas. Proceedings of the 5th Panhellenic Rangeland Congress. pp 119-124. (In Greek with English Abstract).

Landsberg J, James CD, Morton SR, Müller WJ, Stol J (2003). Abundance and composition of plant species along grazing gradients in Australian rangelands. J Appl Ecol 40:1008-1024.

Le Houerou HN (1981). Impact of man and his animals on Mediterranean vegetation. In: Castri F, Goodall DW, Specht RL (Eds.). Mediterranean-type shrublands, ecosystems of the world. Elsevier Science Publishers Co, New York, NY.

pp. 479-521.

Liang Y, Han GD, Zhou H, Zhao ML, Snyman HA, Shan D, Havstad KA (2009). Grazing intensity on vegetation dynamics of a typical steppe in Northeast Inner Mongolia. Rangeland Ecol Manage 62:328-336.

Liu T, Nan Z, Hou F (2011). Grazing intensity effects on soil nitrogen mineralization in semi-arid grassland on the Loess Plateau of northern China. Nutr Cycl Agroecosys 91:67-75.

Liu ZG, Li ZQ, Dong M, Johnston B (2006). The response of a shrub-invaded grassland on the Inner Mongolia steppe to long-term grazing by sheep. New Zeal J Agr Res 49:163-174.

Louhaichi M, Salkini AK, Petersen SL (2009). Effect of small ruminant grazing on the plant community characteristics of semi-arid Mediterranean ecosystems. Int J Agr Biol 11:681-689.

Milchaunas DG, Lauenroth WK (1993). Quantitative effects of grazing on vegetation and soils over a global range of environments. Ecol Monogr 63:327-366.

Milchunas DG, Sala OE, Lauenroth WK (1988). A generalized model of the effects of grazing by large herbivores on grassland community structure. Amer Nat 132:87-106.

Montalvo J, Casado MA, Levassor C, Pineda FD (1993). Species diversity patterns in Mediterranean grasslands. J Veg Sci 4:213-222.

Moreno G (2008). Response of understorey forage to multiple tree effects in Iberian dehesas. Agric Ecosys Environ 123:239-244.

Mosquera-Losada MR, Rodríguez-Barreira S, López-Díaz ML, Fernández-Núnez E, Rigueiro-Rodríguez A (2009). Biodiversity and silvopastoral system use change in very acid soils. Agric Ecosys Environ 131:315-324.

Myers N, Mittermeier RA, Mittermeier CG, Defonseca GAB, Kent J (2000). Biodiversity hotspots for conservation priorities. Nature 403:853-858.

Nair PKR, Gordon AM, Mosquera-Losada RM, Sven EJ, Brian F (2008). Agroforestry. Encyclopedia of ecology. Academic Press, Oxford, pp. 101-110.

Nelson DW, Sommers LE (1982). Total carbon, organic carbon and organic matter. In: Page AL (Ed.). Methods of soil analysis, Part 2. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin. pp. 539-577.

Noy-Meir I, Walker BH (1986). Stability and resilience in rangelands. In: Joss PJ, Lynch PW, Williams OB (Eds). Rangelands: a resource under seige. Aust. Acad. Sci., Canberra, Australia. pp 21-25.

Noy-Meir I (1995). Interactive effects of fire and grazing on structure and diversity of Mediterranean grasslands. J Veg Sci 6:701-710.

Noy-Meir I, Gutman M, Kaplan Y (1989). Responses of mediterranean grassland plants to grazing and protection. J Ecol 77:290-310.

Oba G, Byakagaba P, Angassa A (2008). Participatory monitoring of biodiversity in East African grazing lands. Land Degrad Dev 19:636-648.

Onaindia M, Dominguez I, Albizu I, Garbisu C, Amezaga I (2004). Vegetation diversity and vertical structure as indicators of forest disturbance. For Ecol Manage 195:341-354.

Osem Y, Petrovolotsky A, Kigel J (2002). Grazing effect on diversity of annual plant communities in a semi-arid rangeland: interactions with small-scale spatial and temporal variation in primary productivity. J Ecol 90:936-946.

Papanastasis VP, Mantzanas K, Dini-Papanastasi O, Ispikoudis I (2009). Traditional Agroforestry Systems and Their Evolution in Greece. In: Rigueiro-Rodríguez A, McAdam J, Mosquera-Losada MR (Eds.). Agroforestry in Europe: Current Status and Future Prospects. Advantages in Agroforestry 6:89-109.

Papanastasis VP (1986). Integrating goats into Mediterranean forests. Unasylva 154(38):44-52

Papanastasis VP (2009). Restoration of degraded grazing lands through grazing management: can it work? Restor Ecol 17:441-445.

Pei S, Fu H, Wan C (2008). Changes in soil properties and vegetation following exclosure and grazing in degraded Alxa desert steppe of Inner Mongolia, China. Agric Ecosys Environ 124:33-39.

Perevolotsky A, Landau S, Kababia D, Ungar ED (1998). Diet selection in dairy goats grazing woody Mediterranean rangeland. Appl Anim Behav Sci 57(1):117-131.

Perevolotsky A, Seligman NG (1998). Role of grazing in Mediterranean rangeland ecosystems - Inversion of a paradigm. Bioscience 48:1007-1017.

Pettit NE, Froend RH, Ladd PG (1995). Grazing in remnant woodland vegetation: changes in species composition and life form groups. J Veg Sci 6:121-130.

Plieninger T, Schaich H, Kizos T (2011). Land-use legacies in the forest structure of silvopastoral oak woodlands in the Eastern Mediterranean. Reg Environ Change 11:603-615.

Pluhar JJ, Knight RW, Heitschmidt RK (1987). Infiltration rates and sediment production as influenced by grazing systems in the Texas rolling plains. J Range Manage 40:240-244.

Poschlod P, Bakker JP, Kahmen S (2005). Changing land use and its impact on biodiversity. Basic Appl Ecol 6:93-98.

Robles H, Ciudad C, Vera R, Olea PP, Purroy FJ, Matthysen E (2007). Sylvopastoral management and conservation of the middle spotted woodpecker at the south-western edge of its distribution range. Forest Ecol Manage 242:343-352.

Sasaki T, Ohkuro T, Jamsran U, Takeuchi K (2012). Changes in the herbage nutritive value and yield associated with threshold responses of vegetation to grazing in Mongolian rangelands. Grass Forage Sci 67:446-455.

Sasaki T, Okayasu T, Jamsran U, Takeuchi K (2008). Threshold changes in vegetation along a grazing gradient in Mongolian rangelands. J Ecol 96:145-154.

Shi F, Chen H, Wu Y, Wu N (2010). Effects of livestock exclusion on vegetation and soil properties under two topographic habitats in an alpine meadow on the eastern Qinghat – Tibetan Plateau. Pol J Ecol 58:125-133.

Singer FJ, Schoenecker KA (2003). Do ungulates accelerate or decelerate nitrogen cycling? Forest Ecol Manage 181:189-204.

Smit A, Kooijman AM (2001). Impact of grazing on the input of organic matter and nutrients to the soil in a grass-encroached Scots pine forest. For Ecol Manage 142:99-107.

Spottiswoode CN, Wondafrash M, Gabremichael MN, Abebe YD, Mwangi MAK, Collar NJ, Dolman PM (2009). Rangeland degradation is poised to cause Africa's first recorded avian extinction. Anim Conserv 12:249-257.

Steel RGD, Torrie J H (1980). Principles and Procedures of Statistics. 2nd edition. McGraw-Hill, New York. 481 pp.

Stevenson FJ (1982). Nitrogen-organic forms. In: Page AL (Ed.). Methods of soil analysis, Part 2. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, pp 625-641.

Strid A, Tan K (Eds.) (1997, 2002). Flora Hellenica Vol. 1-2. Patra, 547 + 511 pp.

Suominen O, Danell K (2007). Effects of large herbivores on other fauna. In: Duncan P, Bergstrom R, Pastor J (Eds.). Large Herbivore Ecology Ecosystem Dynamics and Conservation. Cambridge University Press, Cambridge, pp. 383-412.

Tamartash R, Jalilvand H, Tatian MR (2007). Effects of grazing on chemical soil properties and vegetation cover (Case study: Kojour Rangelands, Noushahr, Islamic Republic of Iran). Pakistan J Biol Sci 24:4391-4398.

Tilman D (1997). Community invasibility, recruitment limitation and grassland biodiversity. Ecology 78:81-92.

Todd SW (2006). Gradients in vegetation cover, structure and species richness of Nama-Karoo shrublands in relation to distance from livestock watering points. J Appl Ecol 43:293-304.

Tutin TG, Burges NA, Chater AO, Edmonson JR, Heywood VH, Moore DM, Valentine DH, Walters SM, Webb DA (Eds.) (1993). Flora Europea I. 2nd edition. Cambridge, 581 pp.

Tutin TG, Heywood VH, Burges NA, Moore DM, Valentine DH, Walters SM, Webb DA (Eds.) (1968, 1972, 1976, 1980). Flora Europaea II - V. Cambridge, 469 + 385 + 505 + 452 pp.

van Wieren SE, Bakker JP (2008). The impact of browsing and grazing herbivores on biodiversity. In: Gordon IJ, Prins HTT (Eds.). The Ecology of Browsing and Grazing. Ecological Studies, Springer, Frankfurt, pp. 263-292.

Willoughby MG, Alexander MJ (2007). Rangeland health for native and modified plant communities in the Rough Fescue Ecological Site of the Montane Subregion. Alberta Sustainable Resource Development, Lands Division, Edmonton, Alberta. Publication No. T/150. ISBN No. 978-0-7785-6523-9.

Xie Y, Wittig R (2004). The impact of grazing intensity on soil characteristics of *Stipa grandis* and *Stipa bungeana* steppe in North China (autonomous region of Ningxia). Acta Oecol 25:197-204.

Zhou H, Tang Y, Zhao X, Zhou L (2006). Long – term grazing alters species composition and biomass of a shrub meadow on the Qinghai–Tibet Plateau. Pak J Bot 38(4):1055-1069.

Appendix: Tab. 1 . Species composition at the different distances from the goat corral

	Distance from the goat corral (m)				
Species	50	150	300	600	1200
(1)	(2)	(3)	(4)	(5)	(6)
Woody (total)	**55.01**	**58.06**	**50.28**	**63.09**	**44.09**
Quercus frainetto	13.19	18.90	7.18	14.48	13.85
Acer campestre	-	-	-	-	1.03
Acer tataricum	-	-	-	4.21	1.03
Asparagus officinalis	-	0.46	0.55	-	0.51
Astragalus glycyphyllos	-	-	-	-	0.51
Carpinus orientalis	30.00	27.19	22.65	21.97	2.05
Chamaecytisus austriacus	-	0.46	-	-	-
Chamaecytisus hirsutus	2.73	0.46	0.55	-	-
Cornus mas	-	-	-	3.27	0.51
Cotinus coggygria	2.27	1.84	-	2.34	1.54

(1)	(2)	(3)	(4)	(5)	(6)
Dictamnus albus	-	1.84	1.11	-	1.03
Evonymus verrucosus	-	-	-	-	1.03
Fraxinus ornus	0.45	3.69	3.86	0.46	2.05
Genista carinalis	0.45	0.46	2.77	0.47	2.05
Genista tinctoria	-	-	1.10	0.47	-
Hedera helix	-	-	-	-	5.64
Juniperus oxycedrus	1.36	0.93	1.11	4.67	1.03
Ligustrum vulgare	-	-	-	0.93	-
Lonicera implexa	1.36	1.38	-	2.34	-
Paliurus spina – christi	-	-	-	2.34	-
Quercus cerris	-	-	-	-	0.51
Quercus pubescens	-	-	-	-	1.54
Rosa canina	-	0.46	-	1.87	-
Rosa gallica	0.91	-	-	0.47	-
Ruscus aculeatus	-	-	1.66	0.93	8.20
Sorbus domestica	1.36	-	-	-	-
Thymus longicaulis	0.91	-	7.74	1.86	-
Grasses (total)	**21.36**	**26.26**	**33.70**	**20.56**	**27.17**
Aira elegantissima	-	-	1.10	-	-
Anthoxanthum odoratum	-	-	3.31	0.93	-
Brachypodium pinnatum	7.73	3.69	3.87	3.27	4.10
Brachypodium sylvaticum	-	-	-	-	2.56
Carex depauperata	-	-	-	-	5.12
Carex flacca	8.63	15.67	6.08	2.34	4.62
Cynosurus echinatus	-	0.92	1.66	2.80	-
Dactylis glomerata	0.91	2.76	6.63	6.08	-
Festuca ovina agg.	-	-	-	-	6.67
Lolium perenne	0.45	0.46	-	-	-
Luzula campestris	-	1.38	0.55	0.93	0.51
Melica uniflora	-	-	-	-	1.03
Phleum pratense	-	0.46	-	-	1.54
Piptatherum holciforme	-	-	-	-	0.51
Poa bulbosa	-	-	1.10	0.93	-
Poa nemoralis	1.36	0.92	3.31	1.40	0.51
Poa trivialis	1.81	-	-	1.87	-
Stipa bromoides	0.45	-	6.08	-	-
Forbs (total)	**23.63**	**15.67**	**16.02**	**16.35**	**28.72**
Ajuga laxmannii	-	-	0.55	-	-
Anthemis tinctoria	-	-	-	0.93	-
Anthriscus cerefolium	-	-	-	-	2.05
Aremonia agrimonoides	-	-	-	-	0.51
Capsella bursa-pastoris	-	-	0.55	-	-
Carum sp.	0.45	1.38	0.55	-	-
Centaurea sp.	-	-	-	-	1.03
Cerastium brachypetalum	-	0.46	-	-	-
Comandra umbellata	0.45	0.92	2.76	-	-
Galium laconicum	-	-	-	-	3.08
Galium mollugo	7.27	1.38	0.55	0.93	-
Geranium sanguineum	0.45	-	2.21	-	-
Geum urbanum	-	-	-	-	0.51
Hieracium cymosum	-	-	0.55	-	1.54
Hieracium hoppeanum	-	-	-	0.47	-
Hieracium sp	0.45	-	3.87	-	-
Hypericum montbretii	0.45	-	-	0.47	-

(1)	(2)	(3)	(4)	(5)	(6)
Hypericum perforatum	-	-	-	0.46	-
Inula hirta	2.73	0.46	-	-	0.51
Lapsana communis	-	-	-	0.47	-
Lathyrus laxiflorus	-	-	-	0.93	-
Lathyrus niger	0.45	-	-	0.93	1.03
Muscari botryoides	-	0.46	1.10	0.47	1.03
Paeonia peregrina	0.91	2.30	-	0.47	-
Physospermum cornubiense	1.81	-	-	-	-
Polygonatum odoratum	-	-	-	0.47	7.69
Potentilla micrantha	-	-	-	-	0.51
Silene viridiflora	-	3.23	1.10	-	0.51
Silene viscaria	0.91	-	0.55	0.47	-
Smyrnium rotundifolium	-	-	-	1.87	-
Tamus communis	-	-	0.55	4.21	1.54
Tanacetum corymbosum	2.73	2.76	0.55	0.47	1.03
Teucrium chamaedrys	0.45	-	0.55	-	1.03
Trifolium alpestre	3.64	-	-	-	-
Vicia grandiflora	-	-	-	0.46	-
Viola alba subsp. *scotophylla*	-	2.30	-	1.87	5.12
Bryophytes sp.	0.45	-	-	-	-