Grazing intensity affects soil carbon sequestration in an altitudinal gradient

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Abstract

Grassland management affects soil carbon content and many management practices have been proposed to sequester carbon. One of them livestock grazing has the potential to modify soil carbon content as it affects the soil – plant system, altering the C cycle. The objective of this study was to evaluate the effects of grazing intensity on soil organic carbon in grasslands along an altitudinal gradient in the Mediterranean region. Three grasslands were selected at three different altitude ranges between (800 – 1000 m, 1000 – 1200 m and 1200 – 1500 m) at Central Greece that were under grazing conditions for a long time with different grazing species. Forage production, utilization rate, species richness and soil parameters were measured at each grassland. Species diversity and forage production increased respectively by 25.8% and 56.5% along altitude gradient while forage utilization rate decreased by 53.5%. The results also showed that soil organic carbon increased as grazing intensity decreased at elevated altitudes. These results revealed that moderate grazing intensity could enhance soil carbon accumulation at higher altitudes, contributing to climate change mitigation.

Keywords: climate change, moderate grazing, grasslands, soil organic carbon.

Introduction

Land use may be an important factor mitigating climate change, as it may have an impact on soil organic matter (SOM) storage (Lal 2009). Grasslands are an important land use type in Europe, covering more than a third of the European area, have basic role in animal feeding, provide important regulating ecosystem services, support biodiversity and store carbon in soil. Grazing is one of the most significant factors that could change the soil C stock in grassland ecosystems (Cui et al. 2005), which influences organic matter input and associated soil properties (Steffens et al. 2009, Wiesmeier et al. 2009). Soil organic matter (SOM) is the main reservoir of soil organic carbon (SOC) and soil organic nitrogen (SON) in rangelands and determines soil fertility, water retention, and soil structure (Lal 2004). The amount of organic matter stored in soils is controlled by natural site-specific factors such as climate, topography, land cover and human-induced factors associated with land use (Pineiro et al. 2010). The objective of the present study was to investigate the effects of grazing intensity on soil carbon sequestration along an altitudinal gradient.

Materials and Methods

The research was conducted at Othrys Mountain in central Greece in 2005. Three grasslands were selected at altitude ranges between (800 – 1000 m, 1000 – 1200 m and 1200 – 1500 m), which were subjected to grazing for a long period. In each grassland three experimental areas 50x50m were randomly selected. Fenced experimental plots were established in each zone, in order to protect vegetation from grazing. Forage samples were measured in ten 1.5x1.5m plots while species richness and abundance in 0.5x0.5m. From these data Shannon- Weiner (H′) was calculated according to the formula: $H'=-\sum_{i=1}^{S} Pi \cdot \ln Pi$,

where H′= Shannon- Weiner index and

Pi is the proportion of the individuals

Soil samples were collected at 20cm depth, were the majority of herbaceous plant root occur and soil properties were determined using common soil analysis methods. In the laboratory, soil total nitrogen and soil organic matter concentration were measured by the $K_2Cr_2O_7$ method using the modified Kjeldahl wet digestion procedure of Miller and Keeney (1982). One-way ANOVA was used to compare means in three grasslands. Further differences were evaluated with the LSD posthoc test, at a level of significance of 0.05. The SPSS 15.0 statistical software was used (Kinnear and Gray 2008).

Results and Discussion

Forage production in ungrazed plots was significantly (*P< 0.05*) higher at grasslands above 1200 m, but forage utilisation rate was lower compared to other grasslands, indicating moderate grazing conditions at higher altitudes (Table 1). Furthermore, species diversity index increased by 25.8% along altitude gradient. According to Derner and Schuman (2007), Gao et al. (2007) and Hafner et al. (2012) intermediate levels of grazing can be beneficial to the environment, enhancing nutrient cycling, promoting species diversity and increasing carbon sequestration. In contrast, the increased forage utilisation rate and low productivity in two grasslands at lower altitudes exhibit heavy grazing pressure which could affect soil carbon storage. Recent studies in grasslands ecosystems have been reported that high grazing intensity reduced soil organic carbon concentration compared to low intensity (Han et al. 2008, Klumpp et al.

2009, Martinsen et al. 2011, Sun et al. 2011). Heavy grazing also induces soil compaction which may decrease soil moisture and net primary production (NPP) (Savadogo et al. 2007).

Table 1. Forage production (gr/m^2) in grazed and ungrazed areas, utilization rate and diversity index in the selected grasslands.

Altitude	800- 1000 m	1000 – 1200 m	1200 - 1500 m
Ungrazed plots	48.5a	43.1a	112b
Grazed plots	10.5a	11.8a	52.1b
Forage utilisation rate (%)	78.3a	73.2a	53.5b
Shannon – Weiner (H')	2.44a	2.72a	3.07b

Letters in the same row indicate differences at 0.05 significant level using LSD posthoc test

Table 2. Mean soil attributes from three grasslands

Altitude	800- 1000 m	1000 – 1200 m	1200 - 1500 m
Moisture (%)	17.1a	18.9a	23.5b
Organic matter (%)	31.0a	22.6a	46.1b
Total nitrogen (%)	2.7a	1.8a	5.4b
C:N	11.5a	12.6a	8.5b
Soil texture	SCL	SC	S

Letters in the same line indicate differences at 0.05 significant level using LSD posthoc test (S: Sandy, SC: Sandy-Clay, SCL: Sandy –Clay-Loam)

An overview of selected soil chemical and physical data in three grasslands were presented in Table 2. Grasslands at 1200 – 1500 m altitude range had significant (*P<0.05*) higher soil moisture, nitrogen and organic matter content than grasslands at lower altitudes. The former had lower value of C:N index and sandy soil texture, indicating favourable conditions for organic matter microbial decomposition and nutrient cycling (Drewnik 2006). The latter had high SOM C:N ratios, which was frequently increased under heavy grazing conditions, suggesting potential N limitations for SOM formation under overgrazing (Pineiro et al. 2010).

Conclusions

Livestock grazing has significant effects on C storage in grasslands ecosystems and moderate grazing intensity could enhance soil carbon accumulation at higher altitudes.

References

Cui X., Y. Wang, H. Niu, J.Wu, S. Wang, E. Schnug, J. Rogasik, J. Fleckenstein and Y. Tang, 2005. Effect of long-term grazing on soil organic carbon content in semiarid steppes in Inner Mongolia. *Ecological Research,* 20:519–527.

Derner J.D. and G.E. Schuman, 2007. Carbon sequestration and rangelands: a synthesis of land management and precipitation effects. *Journal of Soil and Water Conservation,* 62:77-85.

Drewnik M., 2006. The effect of environmental conditions on the decomposition rate of cellulose in mountain soils*. Geoderma*, 132:116-130.

Gao Y.H., P.Luo, N. Wu, H. Chen and G.X. Wang, 2007. Grazing intensity impacts on carbon sequestration in an Alpine Meadow on the Eastern Tibetan Plateau. *Research Journal of Agriculture and Biological Science,* 3(6): 642-647.

Hafner S., S. Unteregelsbacher, E. Seeber, B. Lena, X. Xu, X. Li, G. Guggenberger, G. Miehe and Y. Kuzyakov, 2012. Effect of grazing on carbon stocks and assimilate partitioning in a Tibetan montane pasture revealed by $^{13}CO_2$ pulse labeling. *Global Change Biology,*18: 528-538.

Han G., X. Hao, M. Zhao, M. Wang, B.H. Ellert, W. Willms and M. Wang, 2008. Effect of grazing intensity on carbon and nitrogen in soil and vegetation in a meadow steppe in Inner Mongolia. *Agriculture, Ecosystems and Environment*, 125: 21–32.

Kinnear P.R. and C.D. Gray, 2008. SPSS 15 made simple. Psychology Press. Hove.

Klumpp K., S. Fontaine, E. Attard, X. Le Roux, G. Gleixner and J-F. Soussana, 2009. Grazing triggers soil carbon loss by altering plant roots and their control on soil microbial community. *Journal of Ecology*, 97:876–885.

Lal R., 2004. Soil carbon sequestration impacts on global climate change and food security. *Science* 304:1623-1627.

Lal R., 2009. Challenges and opportunities in soil organic matter research. *European Journal of Soil Science* 60:159-168.

Martinsen V., J. Mulder, G. Austrheim and A. Mysterud, 2011. Carbon storage in low-alpine grassland soils: effects of different grazing intensities of sheep.*European Journal of Soil Science* 62:822-833.

Miller R.H and D.R. Keeney, 1982. Methods of soil analysis. Part 2: chemical and microbiological properties, 2nd edn. American Society of Agronomy, Soil Science Society of America, Madison. 228 pp.

Pineiro G., J.M. Paruelo, M.Oesterheld and E.G. Jobbagy, 2010. Pathways of grazing effects on soil organic carbon and nitrogen. *Rangeland Ecology & Management*, 63:109–119.

Savadogo P., L. Sawadogo and D. Tiveau, 2007. Effects of grazing intensity and prescribed fire on soil physical and hydrological properties and pasture yield in the savanna woodlands of Burkina Faso. *Agriculture, Ecosystems & Environment* 118:80-92.

Steffens M., A. Kolbl and I. Kögel-Knabner, 2009. Alteration of soil organic matter pools and aggregation in semi-arid steppe topsoils as driven by organic matter input. *European Journal of Soil Science,* 60:198-212.

Sun D.S., K. Wesche, D.D. Chen, S.H. Zhang, G.L. Wu, G.Z. Du and N.B. Comerford. 2011. Grazing depresses soil carbon storage through changing plant biomass and composition in a Tibetan alpine meadow. *Plant, Soil and Environment*, 57(6):271–278.

Wiesmeier M., M. Steffens, A. Kölbl and I. Kögel-Knabner, 2009. Degradation and small-scale spatial homogenization of topsoils in intensively grazed steppes of Northern China. *Soil and Tillage Research,* 104:299-310.