Black Sea Journal of Engineering and Science
Open Access Journal
e-ISSN: 2619-8991

BSPublishers

Research Article
Volume 1 - Issue 3: 107-113 / Jully 2018
(Cilt 1 - Sayı 3: 107-113 / Temmuz 2018)

THE RELATIONSHIPS AMONG ABOVEGROUND BIOMASS, PRIMARY PRODUCTIVITY, PRECIPITATION AND TEMPERATURE IN GRAZED AND UNGRAZED TEMPERATE GRASSLANDS FROM NORTHERN TURKEY

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Submission: *March 07, 2018;* ***Published:*** *April 01, 2018*
(Gönderi: *07 Mart 2018****; Yayınlanma:*** *01 Nisan 2018)*

Abstract

In this study, it is evaluated the relationship between in climate and variability in above-ground net primary production (ANPP), above-ground live biomass (AGLB) and peak above-ground live biomass (PAGLB) in grazed and ungrazed temperate grasslands from northern Turkey. Rain use efficiency (RUE) is averagely estimated as 0.51±0.11 and 0.85±0.20 gDM.m^{-2}.mm^{-1}.yr^{-1} in grazed and ungrazed stand of the study area respectively. The monthly and annual precipitation indicate to have linear relationship with ANPP and PAGLB according to the regression analysis in ungrazed and grazed stands of study area. RUE of ungrazed stand was generally higher than grazing stand.

Keywords: Grasslands, Grazing, Primary productivity, Rain use efficiency, Turkey

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1. Introduction

Grasslands are one of the most widespread vegetation types worldwide, covering 15 million km^2 in the tropics (as much as tropical forests) and a further 9 million km^2 in temperate regions; together nearly one fifth of the world's land surface (Scurlock and Hall, 1998) and account for ca. 16% (18.9 Gt.yr^{-1}) of the terrestrial global net annual primary production (Zhou et al., 2002).

Biomass and net primary productivity (NPP) is a key variable of terrestrial ecosystems and an important component of the global carbon cycle (Ni, 2004). Estimating NPP has been a central goal of basic and applied ecologist (Sala and Austin, 2000). Biomass harvesting is a common method for estimating aboveground biomass in grasslands. In grassland ecosystems, the amount of aboveground biomass determines forage availability and thus constrains herbivore carrying capacity (Yang et al., 2009).

Regional estimates of NPP are very useful in modelling the regional and global carbon cycle (Li et al., 2013). The precipitation is one of the most effective ecological factors on the above-ground net primary productivity (ANPP) in temperate grasslands (Hu et al., 2007). Spatial and temporal patterns of annual aboveground net primary productivity (ANPP) in the temperate grasslands are determined by regional climatic gradients

(Baer et al., 2003). Rain-use efficiency (RUE) is an effective integral measure for evaluating the response of primary productivity to spatial and temporal changes in precipitation arid and semiarid ecosystems (Le Houérou, 1984). Precipitation extremely effects the amount of aboveground biomass in grasslands and a number of investigations have been mostly used to explain the spatial variation in production (Xiao et al., 1995). The significant relationship has not been obtained between temperature and aboveground biomass in grassland ecosystems (Yang et al., 2009). The effect of precipitation on aboveground biomass may be more effective than temperature in grasslands (Epstein et al., 1997). Global climate change is likely to produce more frequent extreme precipitation and drought events, which may have greater impacts on ecosystem processes than effects of elevated CO_2 and temperature alone or in combination (Bai et al., 2004; Bloor et al., 2010).

Turkey is located in the temperate zone and has a large and ecologically diverse grasslands. Turkey covers a 21,754,690 ha area and 28.3% (644,373 ha) of this area consists of grasslands and pastures (Yalçın et al., 2011). The coordinated studies of the International Biological Programme (IBP) Grassland Biome in late 1960s and early 1970s were based mainly on aboveground biomass changes (Scurlock et al., 2002). Although there is a lot of work that calculates NPP using to biomass measurement in the grassland vegetation at the global level (Milchunas and Lauenroth, 1993; Buis et al., 2009), biomass data is not available for grasslands in Turkey.

The aims of this study is to explore and compare the relationship among aboveground biomass, primary productivity, precipitation and temperature in grazed and ungrazed temperate grasslands from northern Turkey.

2. Materials and Methods

2.1. Study Area

The study area is situated on the coastline of the Central Black Sea Region in the north of Turkey (Figure 1). The natural alluvial grasslands are exist in the Central Black Sea Region adjacent to Kizilirmak and Yesilirmak rivers, respectively. These large areas have been grazed and mowed since 1900s traditionally, but there hasn't been any management or conservation study in the area. This area floristically belongs to the Euxine province of the Euro-Siberian phytogeographical region. The studied grasslands are used as rangeland. The mean annual temperatures in the Kızılırmak and Yeşilırmak deltas are 13.66°C and 14.30°C respectively. The annual rainfall is 672.41 and 922.10 mm in the Kizilirmak and Yesilirmak deltas respectively. The study area was established on the formerly used for grazing grasslands. Hence, this is important precipitation gradient that provides an ideal region for investigating spatial patterns and environmental controls of the amount of aboveground biomass in temperate grasslands. Moreover, there is different information on how climate variation may interact with primary production, which may be important for grasslands with many kind of herbivores.

The study area consists of alluvial sediment soils carried by the Kizilirmak and Yesilirmak rivers. Soil is typically dark grayish brown (Vertisol) and soil depth is meanly 1 m (Yakupoğlu et al., 2010). On average, soil texture is 48% clay, 33% silt and 19% sand.

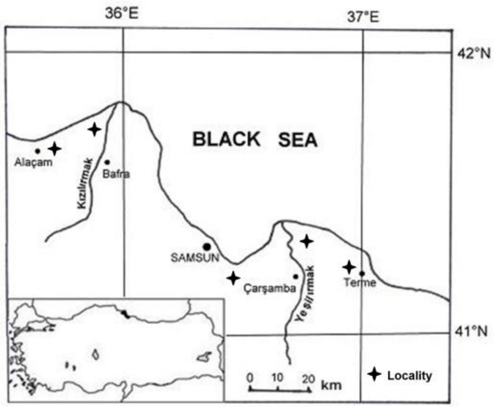

Figure 1. Map of the study area.

The natural vegetation on the area is distributed by temperate grasslands of which consisted by three plant associations (Yalçın et al., 2014). The vegetation in the study area is strongly affected by long-term and overgrazing. Grasslands in the western part of the study area are composed of herbaceous perennial mesophytic and xerophytic species, such as *Hordeum geniculatum* All., *Polypogon monspeliensis* (L.) Desf., *Centaurium pulchellum* (Sw.) Druce and *Romulea ramiflora* Ten. subsp. *ramiflora, Cynodon dactylon* (L.) Pers. var. *dactylon*, *Lotus corniculatus* L. var. *tenuifolius* L., *Bellis perennis* L., *Plantago lanceolata* L:, *Lolium perenne* L:, *Trifolium physodes* M.Bieb. var. *physodes* and *Medicago disciformis* DC. In the eastern part of the study area, grasland vegetation is composed of more herbaceous perennial mesophytic species, such as *Paspalum distichum* L., *Ranunculus ophioglossifolius* Vill., *Trifolium repens* L. var. *repens, Lolium perenne, Cynodon dactylon* var. *dactylon, Plantago lanceolata, Potentilla reptans* L. and *Rumex acetosella* L.

2.2. Sampling of aboveground biomass and data processing

Five localities were selected to obtained aboveground biomass values and estimated net primary production. The main differences are amount of rainfall, soil traits and floristic composition between selected stands. One permanent plot of (5×5 m) was randomly selected and fenced in each stand in 2001 to determine biomass. So, totaly five exclosure obtained to protect from grazing on studied grasslands. The grazing sites have been continuously uncontrolled grazed for at least 20 years before building the exclosures by the horses, cows, sheeps and goats. Aboveground biomass was clipped to the ground surface sequentially in 2001-02 in grazed and ungrazed stands. Aboveground biomass was monthly harvested inside 4 randomly placed 30×30 cm sampling quadrats, and separated into live and recent dead components. After separation, plant material was water-cleaned and oven-dried at 65°C and weighed once a constant weight was attained. Biomass was expressed as weight of dry matter per unit area (gDM.m^{-2}). The same quadrats weren't harvested again during the sampling period. The peak aboveground live biomass (PAGLB) was accepted as the highest aboveground live biomass measured during the sampling periods. There are many methods of estimating annual aboveground net primary production (Singh et al., 1975). It was used by summation of all positive increments in live plus recent dead biomass throughout the entire year (Sala and Austin, 2000) for estimating aboveground net primary production and, was expressed as weight of dry matter per unit area and per year (gDM.m^{-2}.yr^{-1}). The rain-use efficiency (RUE) was estimated as the ratio of ANPP to annual precipitation in gDM.m^{-2}.mm^{-1}.yr^{-1} (Le Houérou, 1984).

Descriptive statistical analyses were performed by using SPSS 21.0 version (Anonymous, 2012). Regression analysis was used to establish quantitative relationship among mean annual temperature (MAT), total annual precipitation (TAP), mean monthly precipitation (MMPT), mean monthly temperature (MMT), aboveground live biomass (AGLB), peak aboveground live biomass (PAGLB) and aboveground net primary production (ANPP). The climate data set includes monthly precipitation and temperature in 2001-02 from the state meteorological and local station in the study area.

3. Results

Total annual precipitation (TAP) accounted for about 21% and 18% of variability in aboveground net primary production (ANPP) in ungrazed and grazed stands of study area respectively (Figure 2). Total annual precipitation (TAP) seemed to have linear relationship with aboveground net primary production (ANPP) in ungrazed and grazed stands of study area. The linear regression analysis indicated that mean annual temperature (MAT) was not significant correlation with aboveground net primary production (ANPP) at in ungrazed and grazed stands of study area (Figure 3).

Mean monthly precipitation (MMPT) accounted for 10 and 17% of variability in aboveground live biomass (AGLB) at in ungrazed and grazed stands of study area respectively (Figure 4). Mean monthly temperature (MMT) accounted for 42 and 15% of variability in aboveground live biomass (AGLB) in ungrazed and grazed stands of study area, respectively (Figure 5).

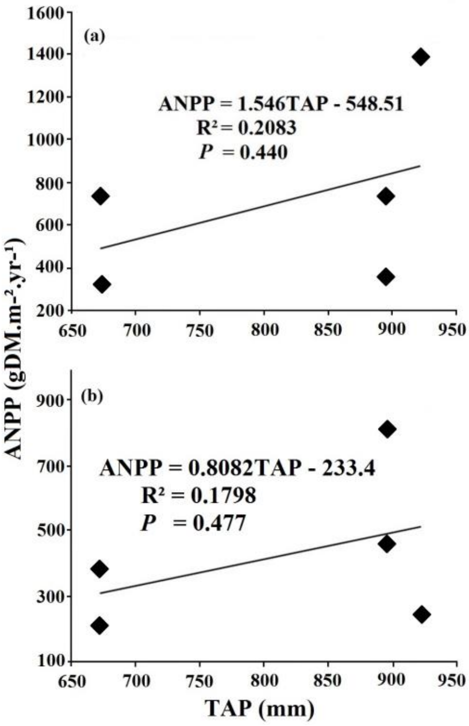

Figure 2. The relationship between total annual precipitation (TAP) and above-ground net primary production (ANPP), (a) Ungrazed stands; (b) Grazed stands.

Total annual precipitation (TAP) indicated to have linear relationship with peak above-ground live biomass (PAGLB) and, accounted for 83 and 24% of variability in peak above-ground live biomass (PAGLB) in ungrazed and grazed stands of study area (Figure 6). The mean annual temperature (MAT) is weakly correlated with aboveground live biomass (AGLB) at in ungrazed and grazed stands of study area. Mean monthly temperature (MMT) accounted for 49 and 22% of variability in peak above-ground live biomass (PAGLB) in ungrazed and grazed stands of study area, respectively (Figure 7).

The rain-use efficiency (RUE) of ungrazed and grazed stands in the study area ranged from 0.39 to 1.50, and from 0.26 to 0.90 gDM.m^{-2}.mm^{-1}.yr^{-1}, respectively. While the mean of rain-use efficiency (RUE) is 0.85±0.20 gDM.m^{-2}.mm^{-1}.yr^{-1} in ungrazed stands, 0.51±0.11 gDM.m^{-2}.mm^{-1}.yr^{-1} in grazed stands of the study area. Although rain-use efficiency (RUE) of ungrazed stand is higher than grazing stand in the first, third and fifth localities, the grazed stand are higher than ungrazed stand in the second and fourth localities (Figure 8).

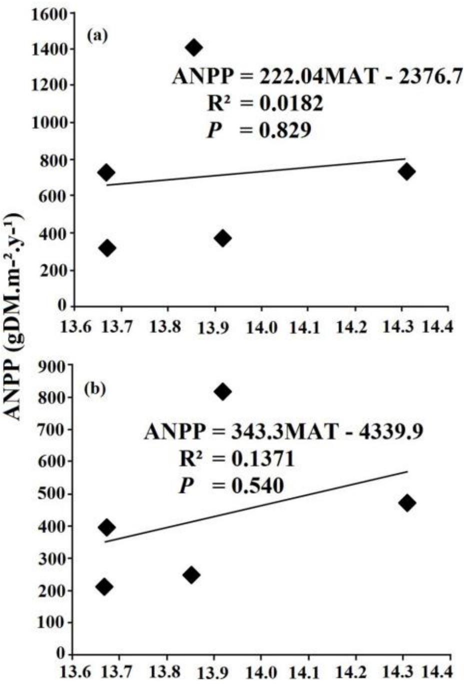

Figure 3. The relationship between mean annual temperature (MAT) and above-ground net primary production (ANPP), (a) Ungrazed stands; (b) Grazed stands.

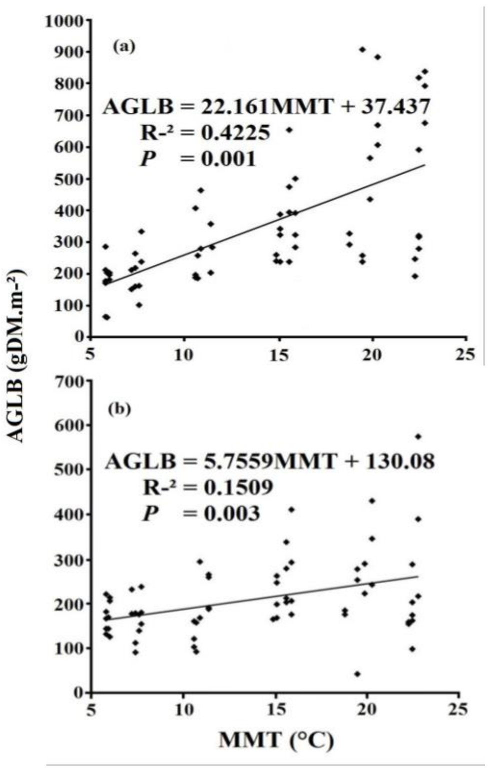

Figure 5. The relationship between mean monthly temperature (MMT) and above-ground live biomass (AGLB), (a) Ungrazed stands; (b) Grazed stands.

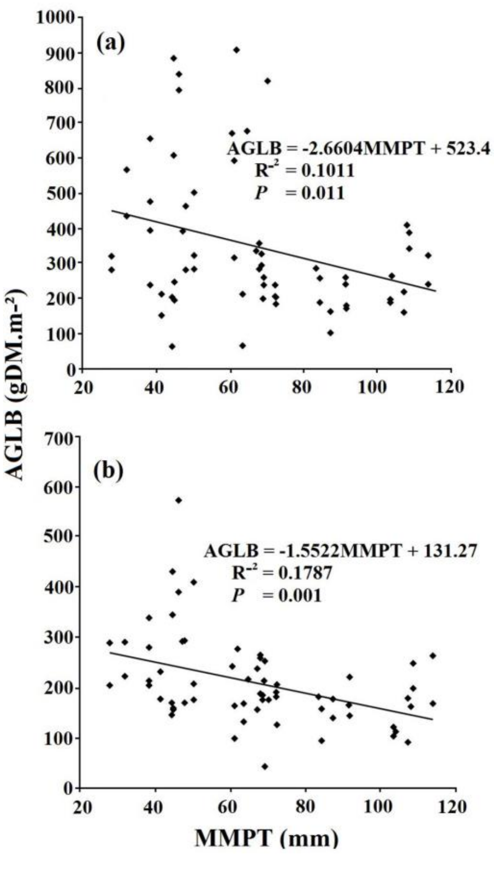

Figure 4. The relationship between mean monthly precipitation (MMPT) and above-ground live biomass (AGLB), (a) Ungrazed stands; (b) Grazed stands.

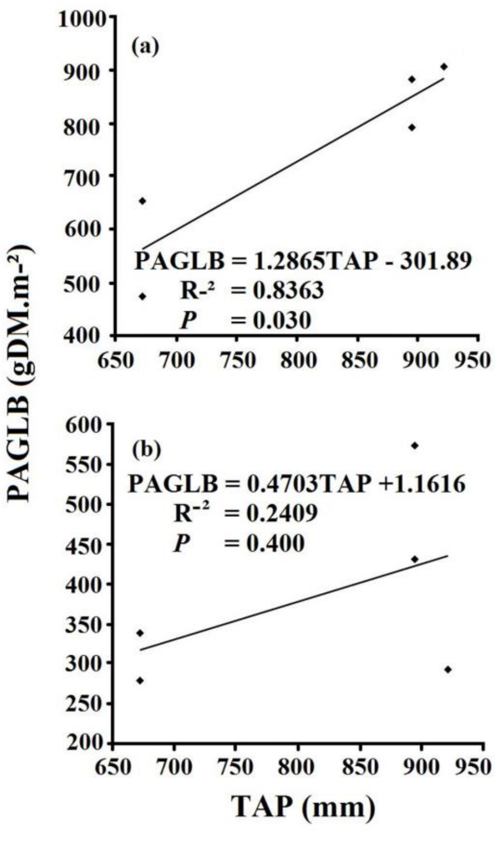

Figure 6. The relationship between total annual precipitation (TAP) and peak above-ground live biomass (PAGLB), (a) Ungrazed stands; (b) Grazed stands.

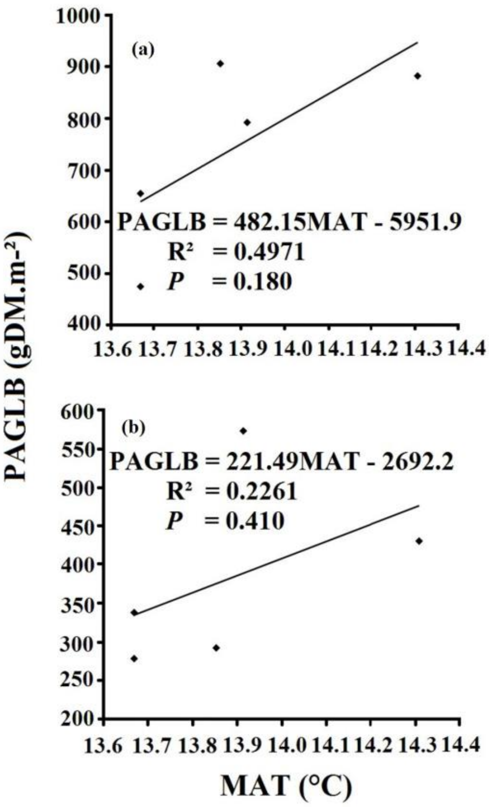

Figure 7. The relationship between mean annual temperature (MAT) and peak above-ground live biomass (PAGLB), (a) Ungrazed stands; (b) Grazed stands.

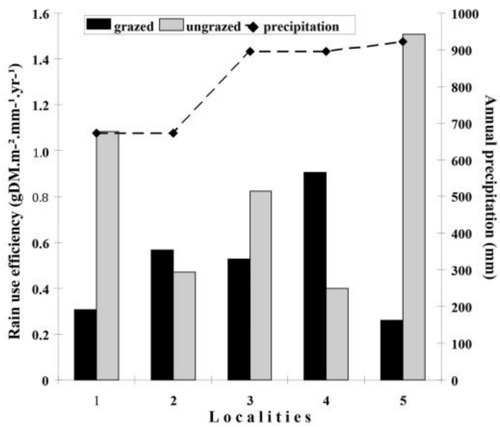

Figure 8. Rain use efficiency (RUE) of the localities, using annual above-ground net primary production (ANPP) and total annual precipitation (TAP) in ungrazed and grazed stands.

4. Discussion

A key integrative measure of ecosystem functioning of which aboveground net primary production (ANPP) increases with mean annual precipitation in space (Sala et al., 1988; Bai et al., 2008). Most of existing studies carried out on North and South America and Tibetian and Mongolian Plateau in China (Ni, 2004; Buis et al., 2009), but a comprehensive understanding of spatial pattern of aboveground net primary production (ANPP) in relation to precipitation in Turkey's lands is yet to be achieved. This study represents the first examination of the spatial variation in aboveground net primary production (ANPP) among grassland ecosystems in Turkey. My results have shown that at the local scale, aboveground net primary production (ANPP) increased significantly with increasing total annual precipitation (TAP). The controlling effect of precipitation on grassland productivity was proved by previous studies (Paruelo et al., 1999; Carlyle et al., 2014). My results don't supported that mean annual temperature (MAT) is an important factor in controlling aboveground net primary production (ANPP). Similar results were observed by previous studies (Epstein et al., 1996; Yang et al. 2009). Aboveground biomas was negatively correlated with mean annual temperature at low precipitation level (MAT< 200 mm), but had weak positive correlations in humid environments (Yang et al. 2009). The negative correlation between aboveground biomass and temperature in very dry environments in alpine grasslands was consistent with that observed in temperate grasslands by Epstein et al. (1997), who claimed that higher temperature caused an increased evaporation and thus a lower plant production.

Aboveground live biomass (AGLB) decreased with increasing monthly precipitation, while increased with increasing mean monthly temperature in this study. Similar results obtained from the study of Bai et al. (2008) in the Mongolia Plateau. Many of studies conducted in temperate grasslands (Briggs and Knapp, 1995; Epstein et al., 1996; 2009; Buis et al. 2009) showed the positive relationship between aboveground live biomass (AGLB) and precipitation. Although it is widely accepted that increasing precipitation promotes the aboveground live biomass, my results is different from other studies in terms of the relationship between aboveground live biomass (AGLB) and precipitation. Most of them harvested only aboveground biomass in growing seasons especially in July and August. They evaluated the relationship between aboveground live biomass (AGLB) and precipitation in this time period. But, I used the linear regression analysis between aboveground live biomass (AGLB) and precipitation for each month throughout year. These differences may have emerged so. The other factors (i.e. nutrient use efficiency or human activity and soil physical properties) possibly strong effects on grassland production (Burke at al., 1997; Baer et al., 2003; Ma et al., 2010). However, total annual precipitation (TAP) indicates to have linear relationship with peak aboveground live biomass (PAGLB) in ungrazed stands of study area. Xiao et al. (1995) reported that annual precipitation indicates to have linear relationship with peak aboveground live biomass (PAGLB) and, accounted for 64% variability of peak aboveground live biomass (PAGLB) of *Stipa grandis*

P.A. Smirn. steppe inner Mongolia, China.

Rain use efficiency (RUE) decrease spatially with increasing aridity and potential evapotranspiration (Le Houérou, 1984). Rain use efficiency (RUE) of ungrazed stands was generally higher than grazing stand in this study. Grazing is one of the important biotic factors that affects on ecosystem and community dynamics (Pucheta et al., 1998; Gibson, 2009). In generally, my results indicated that grazing decreased rain use efficiency (RUE) in temperate grasslands. Early studies showed that drier sites tend to have lower rain use efficiency (RUE) because of low plant density, low production potential, high evaporation potential, and high tolerance to water stres (Noy-Meir, 1973; Grime, 1977).

But, rain use efficiency (RUE) in some grazing stands was higher than ungrazed. Rain use efficiency (RUE) of grazed stands may be affected by several factors, including vegetation composition, edaphic condition and biogeochemical constraints (Le Houérou, 1984; Lauenroth and Sala, 1992; Bai et al., 2008). Furthermore, soil characteristics, such as water holding capacity, texture, permeability, and depth are major determinant of soil water availability and have important effects on the site level rain use efficiency (RUE) (Sala et al., 1988). Long-term grazing able to select can select for genotypes that are more tolerant of current year biomass losses and basal leaf production of plants can increase by grazing (Varnamkhasti et al., 1995). The influence of grazing animal feces on the nitrogen budget is important to stimulate above ground biomass production in addition to precipitation (Milchunas et al., 1995). Because of these, rain use efficiency (RUE) in some grazing stands may be higher than ungrazed in this study.

The ecological consequences of grazing provides valuable information for mitigation and adaptation strategies in response to predicted climate change (Irisarri et al., 2016). My findings in this study may have several implications for understanding ecological impacts of global climate change and better managing grassland ecosystems in Turkey. Global climate change is projected to increase annual temperature by ~4 °C, and to decrease annual precipitation by about 163 mm in the next 100 years in Turkey (Yano et al., 2007; Fujihara et al., 2008). I expect that aboveground net primary production (ANPP) will consequently decrease on a regional scale and that magnitude of change will increase from grassland to meadow steppe because of decrease rain use efficiency (RUE). Finally, a key to increasing the primary production of grasssland ecosystems is to improve RUE, and my study indicates that this can be achieved by conserving biodiversity and controlling overgrazing in northern Turkey.

Nevertheless, more research is necessary to reveal under which conditions a relation between rainfall, temperature, aboveground net primary production and RUE can be expected.

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