Türler ve Habitatlar

(2022) 3(2): 75–80
e-ISSN: 2717-770X
https://dergipark.org.tr/tr/pub/turvehab

Research Article

https://doi.org/10.53803/turvehab.1155739

Below-ground Biomass and Productivity of a Grazed Site and a Neighbouring Ungrazed Exclosure in the Lowland Meadow Vegetation of the Central Black Sea Region of Türkiye

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Received: 04.08.2022 Accepted: 29.08.2022 Published Online: 31.12.2022

Abstract
The subject of this study is to determine the below-ground plant biomass and annual below-ground net primary production of lowland meadows in the Central Black Sea region. This study calculated the annual average amount of below-ground plant biomass, its seasonal distribution, annual primary production, and turnover values in the ungrazed and grazed meadow stands. Below-ground plant biomass, below-ground net primary production, and turnover of grazed stands were higher than in ungrazed stands. This turnover value shows that root biomass is renewed faster in grazed areas. Grazing, annual rainfall, and soil characteristics may have led to these different results.
Keywords: Belowground, biomass, meadow, productivity, Türkiye

Türkiye'nin Orta Karadeniz Bölgesi Ova Çayır Vejetasyonunda Hayvan Otlatılan Bir Alan ve Hayvan Otlatılmayan Korunmuş Bir Komşu Arazinin Yeraltı Biyokütlesi ve Verimliliği

Özet
Bu çalışmanın konusu, Orta Karadeniz bölgesindeki ova çayırlarının yer altı bitki biyokütlesini ve yıllık yer altı net birincil üretimini belirlemektir. Bu çalışmada, hayvan otlatılmayan ve otlatılan çayır topluluklarında yıllık ortalama yer altı bitki biyokütle miktarı ve mevsimsel dağılımı, yıllık birincil üretim ve devir hızı (turnover) değerleri hesaplanmıştır. Hayvan otlatılan meşcerelerin yer altı bitki biyokütlesi, yer altı net birincil üretimi ve devir hızı, hayvan otlatılmamış alanlara göre daha yüksektir. Bu devir hızı değeri hayvan otlatılan alanlarda kök biyokütlesinin daha hızlı yenilendiğini göstermektedir. Otlatma süresi/miktarı, yıllık yağış miktarı ve toprak özellikleri bu farklı sonuçlara yol açmış olabilir.
Anahtar kelimeler: Biyokütle, çayır, toprakaltı, Türkiye, verimlilik

INTRODUCTION

In meadow vegetation, underground plant stems such as rhizomes, bulbs, corms, and fine and coarse plant roots form below-ground biomass. It is reported that the below-ground biomass of meadows exceeds the above-ground biomass by several times (Gao et al. 2008). Below-ground plant biomass and net primary production are one of the most important functional and structural components of meadow ecosystems. Climate change is an urgent and potentially irreversible threat to human society and the planet (Leng et al. 2020). Root production is a critical below-ground

Suggested Citation:
Yalçın, E. (2022). Below-ground Biomass and Productivity of a Grazed Site and a Neighbouring Ungrazed Enclosure in the Lowland Meadow Vegetation of the Central Black Sea Region of Türkiye. *Türler ve Habitatlar* 3(2): 75–80.

component in mediating terrestrial carbon cycling (Wu et al. 2021). Grazing has stimulating, neutral, and suppressive effects on below-ground biomass production, depending on the density, duration, and vegetation characteristics of grazed meadows (Wang et al. 2022).

The Central Black Sea region of Türkiye has lowland meadows called E2.222-Hygromesophile Medio-European lowland hay meadows EUNIS habitat code and name (EUNIS 2022). On the other hand, there is no data on the below-ground biomass and net primary production amount of lowland meadows in Türkiye.

The aims of this study; are (1) to reveal the below-ground biomass values, annual turnover, and annual net primary production amounts of lowland meadows seasonally, (2) to determine whether the below-ground biomass and annual net primary production amounts are different in grazed and ungrazed conditions.

MATERIAL AND METHOD

Study area

The research area is the lowland meadows located within the borders of Samsun province in Türkiye. For the last hundred years, uncontrolled grazing has been done in these meadow areas. This study was carried out in five selected localities, and their altitudes and aspects are 2 m northeast, 2 m northwest, 3 m north, 2m southwest, and 2 m southeast, respectively. The annual average temperature of the study area is 13.66°−14.30°C, and the annual total precipitation is between 672.41 and 922.10 mm (Yalçın et al. 2016). Soil depth is 1 m on average and, soil structure is vertisol (dark grayish brown). *Paspalum distichum* L., *Ranunculus ophioglossifolius* Vill., *Trifolium repens* L. var. *repens, Lolium perenne, Cynodon dactylon* var. *dactylon, Plantago lanceolata, Potentilla reptans* L., *Rumex acetosella* L., *Hordeum geniculatum* All., *Polypogon monspeliensis* (L.) Desf., *Centaurium pulchellum* (Sw.) Druce, *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. distribution in the floristic composition of meadow vegetation (Yalçın et al. 2014).

Sampling of above-ground biomass and data processing

Below-ground biomass and net primary productivity measurement were performed at five localities. A 5×5 m plot was fenced per locality, and five exclosures were created in the research area (Table 1). This way, grazing was prevented, and exclosures and enclosures were formed. Four 8×16 cm wide and 20 cm deep monoliths (soil columns) were randomly taken from the ungrazed and grazed parts. Since the alluvial soil is quite clayey and below-ground biomass is hard to detect, the soil columns were kept in 0.08% sodium hypo chloride solution until they were completely softened (Dahlman & Kucera 1965). The softened soil columns were separated from the coarse soil parts by washing with the "rapid root washing" method developed by Lauenroth and Whitman (1971). Roots separated from coarse soil pieces were floated in the water, washed until no soil particles remained in 2 and 0.5 mm sieves, and dried in an oven at 60°C until the weight stabilized. The dried below-ground biomass was weighed with a precision balance, and the biomass values were determined as grams of dry weight per square meter (g dry weight. m^{-2}) for each month. Below-ground net primary production values were reported by Singh and Yadava (1974), and calculated by Singh et al. (1975) by summing the positive increments values in the biomass method. Accordingly, the sum of the positive increases between the two sampling periods in the below-ground yielded the annual below-ground net production. Below-ground turnover was calculated according to Dahlman and Kucera (1965).

The climate data set includes monthly precipitation and temperature in 2001–2002 from the state meteorological and local station in the study area. Descriptive statistical analyses were performed by using SPSS 20.0 version (IBM 2011). Analyzes were made according to the factorial trial design in random plots. Duncan's multiple comparison test was used to compare the means. It was determined that the variances were homogeneous ($P>0.05$) with Levene's test, and it was determined that the data were in accordance with the normal distribution with the Shapiro-Wilk test. These findings show that the results of the analysis of variance are reliable.

RESULTS AND DISCUSSION

Dinç et al. (2018) determined an average of 420 g/m² below-ground biomass in meadows spreading at an altitude of 550 to 3400 m in the Eastern Black Sea region. Among the grazed stands in this study, the highest annual average below-ground biomass was calculated between 970.57 ± 81.92-2170.70 ± 144.71 g dry weight.m^{-2}, while it was found between 873.02 ± 100.23-1630.28 ± 156.46 g dry weight.m^{-2} for the ungrazed stands (Table 2).

The global average of root biomass in temperate meadows has been reported as 1400 g/m² (Jackson et al. 1996). In this study, while the biomass values measured in the non-grazed stands remained within the limits of the world average, it was observed that they exceeded the average in the grazed stands. Among the grazed stands, the highest annual average below-ground biomass was measured in the first locality in the spring and the lowest in the spring in the fourth locality. Among the ungrazed stands, the highest annual average below-ground biomass was calculated in the fourth locality in winter and the lowest in the first locality in spring. The total below-ground biomass of plants in seminatural meadow studied was characterized by their increase, mostly during the first half of the growing season (Fiala 2010).

The annual below-ground net primary productivity (BNNP) in the study area was calculated between 997.17-2487.13 g dry weight.m^{-2}.yr^{-1} for the grazed stands and between 902.84-1438.38 g dry weight. m^{-2}. yr^{-1} for the ungrazed stands (Table 3). Among the grazed stands, the highest annual below-ground net primary productivity occurred in the third locality and the lowest in the fourth locality. Among the ungrazed stands, the highest annual below-ground net primary productivity was calculated in the first locality and the lowest in the fifth locality. Meadows show highly responsive increases in net primary production to precipitation increases (Garcia-Pausas et al. 2011). However, in this study, an inverse relationship is observed between below-ground net primary production and precipitation. This controversial result suggests that the effect of changing the grazing regime on below-ground production and biomass may depend on the plant species (e.g. their tolerance to grazing) or environmental conditions (Piñeiro et al. 2010).

Annual turnover was calculated between 0.672-1.117 for grazed stands and between 0.528-0.796 for ungrazed stands. While the highest annual turnover value was calculated for the stands in the first locality, the lowest was calculated for the stands in the fourth locality. Among the grazed stands, the highest annual turnover was calculated in the third locality and the lowest in the fourth locality. For ungrazed stands, the highest annual turnover occurred in the third locality and the lowest in the fifth locality. Below-ground rate turnover has been considered a critical component of ecosystem nutrient dynamics and C sequestration (López-Mársico et al. 2015). In this study, below-ground biomass turnover of grazed stands was higher in ungrazed stands. These data obtained in this study indicate that below-ground biomass is replaced faster in grazed areas than in ungrazed areas.

Table 2. Descriptive data of below-ground biomass interaction. Applications; 1: grazed, 2: ungrazed. Seasons; 1: winter, 2: spring, 3: summer, 4: fall. ±: standard error of mean. A difference in letters indicates significant difference between means according to Duncan's test. *P<0.05*.

Applications	Localities	Seasons	Mean annual biomass (g dry weight. m^{-2})
1	1	1	1881.89 ± 82.68b
1	***1***	***2***	***2170.70 ± 144.71a***
1	1	3	1808.06 ± 154.41bcd
1	1	4	1734.06 ± 164.02bcde
1	2	1	1460.97 ± 46.57efghijk
1	2	2	1219.10 ± 89.09ijklmn
1	2	3	1541.96 ± 91.13cdefghi
1	2	4	1554.00 ± 131.44bcdefghi
1	3	1	1374.53 ± 88.80fghijkl
1	3	2	1856.85 ± 137.02bc
1	3	3	1573.75 ± 156.52bcdefgh
1	3	4	1696.52 ± 93.33bcdef
1	4	1	1105.29 ± 61.98lmno
1	4	2	970.57 ± 81.92mno
1	4	3	1246.55 ± 81.61hijklm
1	4	4	1139.41 ± 87.68klmno
1	5	1	1326.76 ± 93.41ghijkl
1	5	2	1616.48 ± 53.44bcdefg
1	5	3	1643.54 ± 65.18bcdefg
1	5	4	1469.99 ± 114.16defghijk
2	1	1	1477.84 ± 118.59defghijk
2	1	2	1630.28 ± 156.46bcdefg
2	1	3	1452.13 ± 89.92efghijk
2	1	4	1489.32 ± 92.45defghij
2	2	1	1419.55 ± 110.69efghijkl
2	2	2	1371.26 ± 63.15fghijkl
2	2	3	1555.07 ± 91.03bcdefghi
2	2	4	1500.03 ± 41.71defghij
2	3	1	1192.60 ± 61.74jklmno
2	3	2	114525 ± 93.37klmno
2	3	3	1496.81 ± 101.57defghij
2	3	4	972.97 ± 68.84mno
2	***4***	***1***	***873.02 ± 100.23o***
2	4	2	1093.37 ± 59.76lmno

2	4	3	1305.53 ± 88.27ghijkl
2	4	4	914.77 ± 80.58no
2	5	1	1411.69 ± 73.83efghijkl
2	5	2	1511.62 ± 112.36defghij
2	5	3	1623.21 ± 107.30bcdefg
2	5	4	1428.85 ± 63.44efghijkl

Table 3. Grazed and ungrazed below-ground net primary productivity (BNNP), turnover values, annual precipitation and temperature data in different localities of the study area.

	Localities				
	1	**2**	**3**	**4**	**5**
Grazed BNNP (g dry weight.m^{-2}.yr^{-1})	2265.67	1653.04	2487.13	997.17	1151.45
Ungrazed BNNP (g dry weight.m^{-2}.yr^{-1})	1438.38	1132.10	1303.61	1091.18	902.84
Grazed Turnover	0.921	0.874	1.117	0.672	0.675
Ungrazed Turnover	0.737	0.639	0.796	0.735	0.528
Precipitation (mm)	672.41	672.43	895.24	895.28	922.10
Temperature (°C)	13.66	13.69	14.30	13.91	13.85

We found that the seasonal dynamics of below-ground biomass as well as BNPP depend on the effects of grazing and climatic conditions of each growing season. In conclusion, it is seen that below-ground biomass dynamics are determined, first by grazing and then by climatic conditions. Above-ground grazing by large herbivores determines vegetation composition and structure and ecosystem functioning.

AUTHOR CONTRIBUTION STATEMENT

In this study; the study idea and design, data collection, analysis and interpretation of the results, and drafting of the article were made by Erkan Yalçın.

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