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Changes in Leaf Area Index, Forage Quality and Above-Ground Biomass in Grazed and Ungrazed Rangelands of Eastern Anatolia Region

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Abstract: Establishing an appropriate poise between forage production and consumption is crucial for sustainable range use. The aim of this study is to determine some plant aspects and canopy structure to generate an apposite management plan. Therefore, two rangelands, continuously grazed that traditional herder grazing system has been applied for centuries and ungrazed for the last 30 years, in Eastern Anatolia Region of Turkey, were selected as the two experimental sites to examine changes in leaf area index (LAI), specific leaf weight (SLW), above ground biomass and dead material, leaf and stem ratio, crude protein, ADF and NDF content of forage, from beginning of the grazing season to the and of the growing season. Leaf area index, in ungrazed site was higher than that of the grazed site. In both treatments, LAI tended to decline after the mid-June, while in grazed site it was below the critical threshold towards the end of June. In grazed site the specific leaf weight increased as the plant growth progressed, and it began to decline in late June. While there was an increase in above-ground biomass on the ungrazed site until the end of June, this increase ceased at mid-June in the grazed treatment. As the stem ratio enlarged with the development of plants, the leaf ratio dwindled. Dead plant material accumulated in the ungrazed site, whereas it did not in the grazed site. Crude protein, ADF and NDF contents of the foliage were higher in the ungrazed plots than those of the grazed plots. The CP content gradually decreased from the beginning to the end of growing season.

Key Words: Rangeland, leaf area index, specific leaf weight, crude protein, ADF, NDF

Doğu Anadolu Bölgesinde Korunan ve Otlatılan Mera Kesimlerinde Toprak Üstü Biyoması, Ot kalitesi ve Yaprak Alan İndeksinin Değişimi

Öz: Ot üretimi ve tüketim arasında doğru bir denge kurmak meraların uygun kullanımı için hayati öneme sahiptir. Bu çalışmanın amacı, uygun mera yönetim planına katkıda bulunmak için bazı bitki ya da bitki örtüsü ile ilgili özellikleri belirlemektir. Bu çalışmada Doğu Anadolu Bölgesinin korunan ve çok uzun yıllardır çobanla otlatılan iki farklı mera kesiminde otlatma mevsiminin başlangıcından yaz dormansi döneminin başlangıcına kadar geçen sürede otun ADF, NDF, ham protein içeriği, yaprak sap oranı, ölü materyal, toprak üstü biyoması, spesifik yaprak ağırlığı, yaprak alan indeksindeki değişimleri incelenmiştir. Korunan kesimde yaprak alan indeksi otlatılan kesimden daha yüksek olmuştur. Her iki kesimde de haziran ayının ortalarından sonra azalma eğilimine giren YAI otlatılan kesimde haziran ayının sonlarına doğru kritik sınırın altına düşmüştür. Spesifik yaprak ağırlığı bitkide gelişme ilerledikçe artmış ve Haziran ayının sonlarında otlatılan kesimde azalmaya başlamıştır. Haziran ayının sonuna kadar korunan kesimde toprak üstü aksamda artış olurken, bu artış otlatılan kesimde Haziran ayının ortasında durmuştur. Sap oranı bitkinin gelişmesiyle artarken yaprak oranı azalmıştır. Ölü materyal birikimi korunan alanda tespit edilmişken, otlatılan kesimde ölü materyal birikimi gerçekleşmemiştir. Otun ham protein, ADF ve NDF içeriği otlatılan alanda korunan alandan daha yüksek olmuştur. Genellikle ham protein içeriği otlatma mevsimi başlangıcından büyüme dönemi sonuna kadar doğrusal olarak azalmıştır.

Anahtar Kelimeler: Mera, yaprak alan indeksi, spesifik yaprak ağırlığı, ham protein oranı, ADF, NDF

Introduction

All green plants can contribute to primary production by photosynthetic activity in leaves that play a major role in this process. Therefore, adequate leaf area should be critical to plant regeneration for a constant primary production. Ideally, leaf area index (LAI) among forage crops varies between 3 and 11, depending on the morphological and anatomical structure of the plants (Nelson and Moser 1995). However, for the rangelands, grazing and production take place simultaneously; LAI should be preferably between 1 and 2, so as to establish a fine poise among grazed plant portion, leaf deaths and total production

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(Vallentine 1990). Therefore, retaining adequate leaf area on rangeland during the active growing period plays an immense role for sustainable production.

Plant leaves grow in two successive processes, the first one is cell division and the second is the enlargement of these cells (Dahl 1995). During the cell enlargement processes, specific leaf weight (SLW) per unit increases because of increase in intracellular structural matter (Duru et al. 2004). There is a close relationship between SLW and photosynthetic efficiency. Young leaves are more effective in photosynthesis (Wilson and Cooper 1969), so, as the SLW increases, photosynthetic efficiency decreases (Barnes et al. 1969). Biomass acceleration in plants relate with the maintenance of photosynthetic activity. While a continuous biomass built-up occurs in ungrazed rangelands during the growing season (Koc and Gokkus 1996), however, in grazed rangelands it remains stable or decreases, depending on grazing intensity (Lemaire and Agnusdei 2000). As a consequence, amount of live and dead plant material were significantly lower in grazed pastures in comparison with the ungrazed ones.

Forage quality can be defined as the relative performance of animals (Buxton et al. 1996). In general, higher levels of cell-soluble, crude protein and minerals are considered as criteria for higher nutritive quality. These components of forage decline substantially with the advanced plant growth and reach the lowest level when plants become dormant (Koc and Gokkus 1994) as in all steppe vegetation. The changing trend of nutritive component of forage shows great differences among range types because the timing and length of growing season differ among them due to climate (Holechek et al. 2004). Nutritional quality also indicates great differences among plant components; such as leaves having usually higher nutrient quality than stems (Bakoglu et al. 1999a), and increases of stem ratio with the further plant growth leaf ratio decreases (Bakoglu et al. 1999b). As a result of this process, forage quality lessens substantially towards the end of growing season. Effect of grazing on plant re-growth forage quality is generally higher in grazed swards; because of this young plant tissues are more nutritious than dead or mature plant (Lyons et al. 1996).

The objective of this study was to determine the alterations in the LAI, SLW, leaf-stem ratio, above ground biomass and forage quality in grazed and ungrazed rangelands, and accordingly to develop an appropriate management plans.

Materials and Methods

This study was carried out in Erzurum Province of Turkey during 2004 in two different sites, where were located in the ungrazed rangelands of the Agriculture Faculty Research Farm of Ataturk University, and in the continuously grazed rangelands of Tuzcu village, 3 km far from the former site. Both sites are located on the north aspect of Palandoken Mountain foothills. The ungrazed range sites have been protected from grazing for the last 30 years, the openly year-round grazed experimental site has been subject to the traditional herder grazing system for centuries heavily. In the experimental sites, soil parent material, vegetation, altitude etc., and environmental characteristics were similar, except grazing.

The determinations of soil textures, soil pH, soil lime content, soil available phosphorus content, plant available potassium, and soil organic matter content were performed by using hydrometer method (Gee and Bauder 1986), pH meter (Mc Lean 1982), Scheibler calcimeter (Nelson 1982), moliybdo phosphoric blue color method (Olsen and Sommers 1982), a flame photometry (Thomas 1982), the Smith-Weldon method (Nelson and Sommers 1982), respectively.

Ungrazed site soil had a sandy-clay texture, neutral pH (7.8), low lime ($CaCO_3$) ratio, poor phosphorus (41.6 kg/ha) and rich potassium contents (1160 kg/ha), low organic matter content with barely 2.7 percent portion. In grazed experimental area, soil possessed a sandy-loamy texture, neutral pH (6.4), and poor lime and phosphorus contents (15.4 kg/ha, high potassium (2200kg/ha) and low organic matter (2.1%) contents. In the study area, altitude is just about 2000 m. Long term average annual temperature, precipitation and relative humidity were 5.7ºC; 424.6 mm and 63.6%, respectively. For the experimental year, these values were recorded as 4.4 ^{o}C, 440.8 mm, 60.9 % in that same order. Table 1 shows the weekly precipitation, temperatures and humidity values for the study period.

The plant samples were taken at weekly intervals, stretching from 24th May (initation of grazing) to the initiation of the summer dormancy. In each site, ten samples were weekly cut in an area of 0.25 m^2 (0.5m x 0.5m), from 24th May to 5th July. Ten tillers or shoots of the predominant plant species were chosen in the range sites. Dominant species were *Festuca ovina* (sheep fescue), *Agropyron intermedium* (intermediate wheatgrass) for grasses and *Trigonella foenum-graecum* (fenugreek), *Medicago varia* (hybrid alfalfa), *Onobrychis sativa* (sainfoin) for legumes and *Falcaria vulgaris* (sickleweed), *Artemisia spisigera* (sagebrush) for the species from other families.

Table 1. Weekly records of precipitation, temperature and humidity in experimental sites.

Dates	May 24th	May 31st	June 07th	June 14th	June 21st	June 28th	July 05th	Total-Aver.	LTA	Study Year
Precipitation (mm)	16,9	22,4	2,6	0,0	9,0	19,2	9,9	80,0	424,6	440,8
Temperature ºC	7,4	13,0	13,2	12,6	15,9	16,6	15,3	13,4	5,4	4,4
Humidity (%)	58,6	58,6	56,0	48,9	53,3	52,9	47,1	53,6	63,6	60,9

Plant leaves were separated to measure leaf area (Knops and Reinhart 2000) by using a CI 202 PORTABLE digital leaf area meter. Subsequently, leaves were oven-dried at 80ºC until reaching a constant weight and specific leaf weight (SLW) for each species was calculated by dividing total leaf weight (mg) with total leaf area (cm^2), and were articulated as mg cm^{-2}. All plant samples were classified as leaf, stem or dead material, and all samples were oven-dried at 80ºC during 24 hour. After that, LAI was calculated by summing of the weighted average of (SLW x leaf weight) of each species for each sampling area (0.25 m^2) (LI-COR, 1992). Leaf and stem ratio were estimated as a proportion for each component in total live biomass. All samples were separated into live and dead material, were oven-dried at 80ºC during 24 hour, and then were expressed as g m^{-2}. After measuring samples weights, all live plant components were mixed and grinded to pass a 2 mm sieve. Crude protein content was determined by the Kjeldahl method (Jones 1981). The analyses of the acid and neutral detergent fiber (ADF and NDF) were performed with the use of methods suggested by Van Soest (1963).

The SAS statistical package of the SAS institute was employed to conduct the analysis of variance for all experimental data. Means were seperated by using the Least Significant Difference test (LSD).

Results

Leaf area index inclined to increase up to the date June 7th, and after then it tended to decrease, and reached to the lowest level at the last sampling date (Figure 1). In grazed plots, LAI was 2.29 at the beginning of the grazing season (May 24) and did not have any significant change until the mid-June. After that it began to decrease again and reached the lowest level in the last sampling date (July 5th) (Figure 1). There was a significant interaction between time and site in respect to LAI. SLW was higher in ungrazed area than that of grazed site (Figure 2). In ungrazed plots, SLW was 3.93 mg cm^{-2} at the first sampling, but starting from the second sapling date (May 31) it steadily and significantly increased until late June (21 June) and then it began to decrease (Figure 2). However, in ungrazed site, the SLW steadily accelerated up to the fifth sampling date (June 21), and after that it remained unchanged (June 28) (Figure 2). The interaction of (site x time) was significant for changes of SLW between the sites.

In ungrazed plots, the above-ground biomass was constantly increased until the fifth sampling (June 21), afterwards it had a declining tendency (Table 2). On the other hand, it did not differ significantly between the first and second samplings (i.e. until May 31st) in grazed site, and it remained constant in the third,

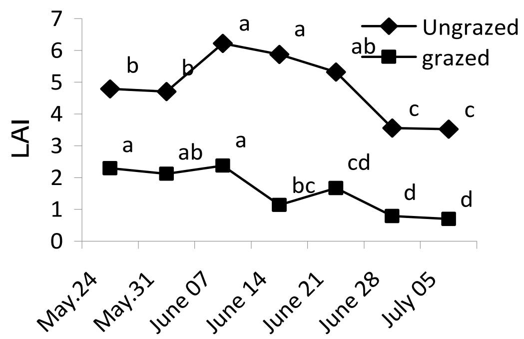

Figure 1. Changes of leaf area index (LAI) on the ungrazed and grazed sites during the growing season, a-d; P<0.01

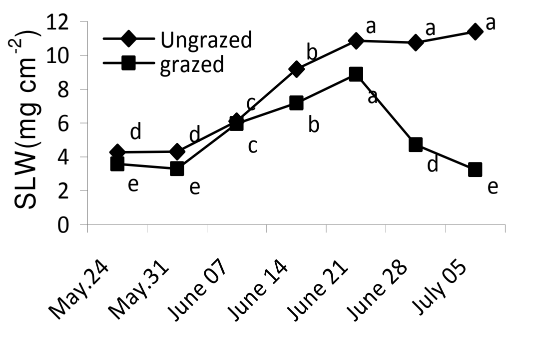

Figure 2. Changes of specific leaf weight (SLW) on the ungrazed and grazed sites during the growing season, a-e; P<0.01

Table 2. Changes of above ground live biomass and dead material on the ungrazed and grazed sites during the growing season

Sampling Date	Above ground biomass (g m^{-2})			Dead material (g m^{-2})		
	Ungrazed	Grazed	Average	Ungrazed	Grazed	Average
May 24th	79.5 f	33.0 b	56.3± 5.7 e	82.6 bc	2.0	42.3±9.4 bc
May 31st	103.3 e	30.4 bc	66.9±8.4 e	90.3 bc	0.0	45.2±11.2 bc
June 07th	128.3 d	43.0 a	85.6±10.5 c	88.7 bc	0.0	44.4±10.4 bc
June 14th	266.3 b	47.8 a	157.1±25.6 b	127.3 a	0.0	63.6±15.0 a
June 21st	300.3 a	48.5 a	174.4±29.4 a	95.7 b	0.0	47.9±11.1 b
June 28th	209.6 c	27.6 bc	118.6±21.3 d	78.9 cd	0.0	39.5±9.2 cd
July 05th	197.8 c	24.5 c	111.2±20.4 d	66.7 d	0.0	33.4±7.9 d
Average	183.6±9.7 a	36.4±1.3 b	110.0±7.9	90.0 ± 2.9 a	0.28 ±0.1 b	45.2 ± 4.1

a-f; Means in the same column with different letters are significant (P<0.01)

fourth and fifth sampling date, then it began to decline (Table 2). In ungrazed experimental plots, the dead plant material of the first sampling was 82.6 g m^{-2}, after that it increased up to 127.3 g m^{-2} (mid-June), but decreased to 66.7 g m^{-2} (at last sampling date). Apparently, there was not any dead material in grazed sites throughout the samplings (Table 2). Stem ratios were 26% for ungrazed and 47% for grazed treatments (Table 3). The mean stem ratio increased steadily until to June 14th, afterward it has no any significant change in neither range site (Table 3). Leaf ratio was higher in ungrazed site (74%) compared to grazed site (53%), and in ungrazed plots leaf ratio gradually decreased throughout the advancing growing season (Table 3). In grazed areas, the significant alterations occurred among the leaf ratios of the first three sapling dates, after that it remained constant for the last four samplings (Table 3).

Mean crude protein, ADF and NDF contents of the forage were higher in ungrazed treatment (14.6% 25.1% and 53.6%) compared to grazed site (Table 4). In ungrazed plots, from the initial grazing season to the beginning of the summer dormancy, crude protein content decreased but ADF and NDF increased (Table 4). At the first sampling (i.e. plant growth initiation), crude protein, ADF and NDF contents were 17.9%, 20.7% and 49.7% for the ungrazed site and 12.0%, 19.2% and 45.7% for the grazed site, respectively. At the initiation of the grazing season, the ungrazed rangeland had the highest crude protein content (17.9%), which gradually decreased down to 12.1% at the last sampling (July 5th) (Table 4). The ADF and NDF contents increased steadily in both treatments (Table 4). The ungrazed rangeland had the highest ADF (29.7%) and NDF (58.4%) contents at the last sampling (i.e. the summer dormancy). However, the grazed site did not have any significant difference for the crude protein among the samplings (Table 4).

Discussion

In highland areas, environmental conditions (i.e. especially true for temperature) become favorable in spring, growth initiation starts in perennial plants, as it occurred in our experiment. Thereafter, the above-ground plant parts steadily enlarge, for example, the LAI increment lasted between May 24th and June 28th in ungrazed site. Under favorable conditions, plants develop new tissue and organ, like foliage, stem, tiller, and shoot etc., in parallel with the advanced time. Therefore, above ground live biomass and LAI increase constantly during the plant vegetative growth (Dahl 1995). The decrease in LAI, after late-June, occurred due to the senescence of old leaves and some plant parts in dry period. Likewise, after that the above-ground live biomass had a decreasing trend (Table 2). It is well known that a dry seasonal period triggers drought stress in perennial herbaceous plants, causing summer dormancy and drying-out of all above ground plant parts (Brown 1995). This partly explains the decreases in above ground live biomass and LAI in ungrazed site after late-June.

It appeared that LAI did not have any significant change between the first and fourth samplings, which might be explained by restoring the foliage defoliation with the compensatory leaf production, because this is the period when the plants grow actively in the region (Koc and Gokkus 1996). In grazed site, after late-June, the rapid decrease in LAI stemmed from the decreasing leaf production rate, which mainly occurred due to drought and excessive grazing. Differences between grazed and ungrazed plots for the LAI value were mostly caused by the significant interactions of the treatments and sampling times.

The SLW steadily increased over time in ungrazed site (Table 2). After the ceasing of the cell division, the process for cell enlargement begins in plant leaves. This results in the cellulose accumulation, which has a high molecular weight (Tan et al. 2000). This process was the reason for increasing SLW in ungrazed site across the samplings. The SLW showed rapid increases between the samplings (June 7th and June 21st) in grazed site (Figure 1). During this period the regional rangelands produced the highest above-ground biomass accumulation (Koc and Gokkus 1996). Since the rate of above ground biomass production exceeded the rate of defoliation, leaf age might get older in the plants during this period in grazed site, thus increasing SLW in grazed area.

Table 3. Changes of leaf and stem rate on the grazed and ungrazed sites during the growing season

	Leaf rate (%)			Stem rate (%)		
Sampling Date	Ungrazed	Grazed	Average	Ungrazed	Grazed	Average
May 24th	87 a	75 a	81±3.5 a	13 b	25 c	19±3.5 c
May 31st	87 a	61 b	74±3.7 a	13 b	39 b	26±3.8 c
June 07th	86 a	74 a	80±2.6 a	14 b	26 c	20±2.6 c
June 14th	69 b	47 c	58±3.5 b	31 a	53 a	42±3.5 b
June 21st	62 b	41 c	52±3.3 bc	38 a	59 a	49±3.3 ab
June 28th	64 b	36 c	50±3.6 c	36 a	64 a	50±3.6 a
July 05th	64 b	35 c	50±4.7 c	36 a	65 a	51±4.7 a
Average	74±1.7 a	53±2.5 b	64±1.7	26 ±1.7 b	47±2.5 a	37±1.8

a-c; Means in the same column with different letters are significant (P<0.01)

Table 4. Changes of crude protein, ADF and NDF content (%) on the ungrazed and grazed sites during the growing season

Sampling Date	Crude Protein			ADF			NDF		
	Ungrazed	Grazed	Average	Ungrazed	Grazed	Average	Ungrazed	Grazed	Average
May 24th	17.9 a	12.0	15.0±2.5	20.7 e	19.2 d	20.0±0.5 e	49.7 d	45.7 c	47.7±2.0 b
May 31st	16.6 ab	11.8	14.2±2.5	24.4 cd	21.9 c	23.2±1.5 c	51.4 cd	44.4 c	47.9±3.5 b
June 07th	15.1 bc	12.7	13.9±0.9	24.3 cd	19.5 d	21.9±1.5 cd	50.9 cd	41.0 d	46.0±3.4 b
June 14th	14.7 bc	12.5	13.6±0.1	22.6 c	19.8 d	21.2±0.1 de	52.9 c	44.9 c	48.9±0.1 b
June 21st	12.9 cd	12.1	12.5±0.1	26.6 b	26.0 b	26.3±0.1 b	55.5 b	51.5 b	53.5±2.0 a
June 28th	13.1 cd	12.4	12.8±0.5	27.3 b	26.7 b	27.0±0.5 b	56.0 b	55.0 a	55.5±0.5 a
July 05th	12.1 d	12.0	12.1±0.1	29.7 a	28.7 a	29.2 ±0.5 a	58.4 a	55.2 a	56.8±1.5 a
Average	14.6 ±0.7	12.2±0.1	13.4±0.5	25.1±1.2	23.1±1.5	24.1±0.9	53.6±1.3 a	48.2±2.2 b	50.9±1.4

a-e; Means with different letters are significant at (P<0.01) level.

After June 28th, there was insignificant change in SLW in ungrazed site, whereas it had a significant decrease in grazed site. This result could be probably due to grazing effect, because the grazing reduces excessive transpiration surface and promotes more efficient use of soil moisture. Therefore, the availability of soil moisture in grazed treatment extends the consumption in comparison with the ungrazed sites. On the other hand, because of the promotional effect of grazing on plant re-growth under favorable conditions (i.e. about 30 mm precipitation was recorded for this interval) the new leaves might regenerate during this period in grazed site. Accordingly, SLW might decrease in grazed sites after June 28th. This difference of the SLW trend between ungrazed and grazed treatments must be the main reason for time and site interaction.

While the constant increase in the above ground live biomass until the late-June in ungrazed area can be related with the subsequent plant growth, the decrease can be associated with the senescence of plant leaf and stems, occurring in the dry summer period (Koc and Gokkus 1996, Demirbağ 2008). In grazed site, the enlargement of above ground live biomass until the late-June must originate from that plant growth rate exceeding the grazed plant part. After that, plant growth were slowed down, but grazing continued at the same intensity, causing to decline in above ground live biomass in grazed site. Molinar et al. (2001), stated that the amount of residues at the beginning of July was nearly at the critical threshold (i.e. 30 g m^{-2}) with respect to soil and vegetation conservation. However, in the region, the traditional grazing period lasts for at least 3 months more after this critical point.

In light of these results, it can be concluded that the current stocking rate is higher than the actual carrying capacity in grazed site. Therefore, the stocking rate should be re-assessed in terms of the perspectives for the sustainable range use. If not, range degradation will be the inevitable consequence.

Grasses are the dominant plants in the rangelands because of their ecological natures, particularly adaptation to limited the precipitation regime (Holechek et al. 2004). Although it is similar in all the plants, leaf is the first apparent above ground part, and thereafter stem elongation occurs in grasses (Dahl 1995). Therefore, as leaf ratio decreases stem ratio increases in line with the advanced plant growth. As a result, leaf ratio constantly decreased in ungrazed site, and the similar trend was also observed in grazed site. However, plant leaf ratio was always lower in grazed site compared to ungrazed site, which might be the result of the preference amongst grazing animals for the leaves (Koc and Gokkus, 1993).

Obviously, the presence of excessive dead material in ungrazed and its absence in grazed site related to the grazing effect. The dead material accumulation in grazed site was not likely to occur due to the constant removal of the consumable plant part, but apparently it accumulated in the absence of grazing in ungrazed site. The reduction in the dead material of ungrazed site during the advanced plant growth might be related to transport by the wind and other environmental factors (rodents, decay etc).

Forage quality declines with the advancing maturity because of the proportion of leaves in forage. As the CP concentration decreases, the ADF and NDF contents increase together with the advancing plant maturity (Messman et al. 1991; Lacefield et al. 1999; Linn ve Martin 1999). In the ungrazed site, similar results with respect to CP, ADF and NDF contents can be attributed to plant maturity, whereas the unchanging CP content and increasing ADF and NDF contents in grazed area can be ascribed to the grazing effects.

In conclusion, it can be stated that even if the daily forage production was higher compared to daily defoliation rate under current stocking rate during the period from the beginning of grazing to the end of June, thereafter, daily forage accumulation rates were declined and ceased at the beginning or middle of July. However, grazing continues at same intensity up to the end of November. In order to compensate for the forage shortage during the dormant period, extra forage produced during the active growing season in highland rangelands of the Eastern Anatolian Region were used as in similar ecological conditions in Turkey, where summer dormancy occurred which is also a characteristic of steppe vegetation. Therefore, it is crucial to establish a good production and consumption balance in the rangelands during the active plant growing period in order to ensure sustainable use of steppe rangelands. However, under current stocking rates, the residuals on the rangelands at this time reached critical value with respect to soil and plant conservation against environmental factors (runoff, insects, over temperature near crown etc.) by considering sustainable range management perspectives. Therefore, new plans incorporating range carrying capacity are urgently required in the region. Otherwise, range degradation will continue in the region.

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