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Forage yield and nutritive value of forest gap rangelands under differing Scotch pine canopy coverage

Rendimiento forrajero y valor nutritivo de los pastizales de la brecha forestal bajo diferentes coberturas de dosel de pino silvestre

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SUMMARY

Rangeland areas have great value as a quality source of roughage for livestock. As these areas lose their productivity, grazable areas within the forest will become alternative sources of forage for livestock. Therefore, determining the quality and quantity of forest gap understory vegetation at different tree frequencies is very important for efficient management of livestock and sustainable natural resources. This study was carried out in Scotch pine (*Pinus sylvestris* L.) forests to determine the forage quality of forest gap understories. The study area was separated into three different sites (open site, sparse site and dense site) based on tree canopy coverage. Among the examined plots, it was determined that dry matter yields were 823 – 1,486 kg ha^{-1}, Crude Protein (CP) 9.59 - 12.87 %; Neutral Detergent Fiber (NDF) 53.27 - 58.49 %; Acid Detergent Fiber (ADF) 32.40 - 37.33 % and Relative Feed Value (RFV) ranged between 95.32 - 112.32. The highest CP, NDF, and ADF contents and the lowest dry matter yield were found in the densely tree-covered area. While dry matter yield decreased, the contents of CP, ADF and NDF increased with increasing tree canopy density. In conclusion, the forest gaps (open and sparse tree canopy) can be used for grazing under sustainable grazing management practices to alleviate forage shortages in the region and provide extra income for rural people. This practice can contribute to sustainable rural development of understory grazing in the forest and forest edge settlements.

Keywords: forage quality, dry matter yield, crude protein, relative feed value.

RESUMEN

Las zonas de pasto tienen una gran importancia como fuente de forraje de calidad para el ganado. A medida que estas áreas pierden su productividad, las zonas pastoreables dentro del bosque se convertirán en fuentes alternativas de forraje para el ganado. En este sentido, la determinación de la calidad y cantidad de la vegetación del sotobosque del bosque en diferentes frecuencias de árboles es muy importante para una gestión eficiente del ganado y de los recursos naturales. Este estudio se llevó a cabo en bosques de pino silvestre (*Pinus sylvestris* L.) para determinar la calidad forrajera del sotobosque de los bosques. El área de investigación se separó en tres sitios diferentes (sitio abierto, sitio escaso y sitio denso) en función de la cobertura de las copas de los árboles. En las parcelas examinadas, se determinó que los rendimientos de materia seca fueron de 823 - 1.486 kg ha^{-1}, la proteína cruda (PC) de 9,59 - 12,87 %; la fibra neutra detergente (FND) de 53,27 - 58,49 %; la fibra ácida detergente (FAD) de 32,40 - 37,33 % y el valor alimenticio relativo (VRA) osciló entre 95,32 - 112,32. Los contenidos más altos de PC, FND y FAD y el menor rendimiento de materia seca se determinaron en la zona densamente arbolada. Mientras que el rendimiento de materia seca disminuía, los contenidos de PC, FND y FAD aumentaban a medida que aumentaba el dosel de los árboles. En conclusión, los vacíos forestales (dosel arbóreo abierto y escaso) pueden utilizarse para el pastoreo bajo los principios de gestión del pastoreo sostenible para aliviar la escasez de forraje en la región y proporcionar ingresos adicionales a la población rural. Esta investigación puede contribuir al desarrollo rural sostenible del pastoreo en el bosque y en los asentamientos del borde del bosque.

Palabras clave: calidad del forraje, rendimiento de materia seca, proteína cruda, valor alimentario relativo.

INTRODUCTION

The Eastern Anatolia Region in Turkey has a wide rangeland area, making up approximately 35 % of the country's rangelands (TurkStat 2012). Representing the country's most important natural resources, these areas have the potential to provide inexpensive and quality sources of forage for livestock (Altın *et al.* 2011). In addition to providing animal nutrition, they serve many other functions, such as biodiversity and genetical resources, soil conservation and water resources, habitat for wildlife, and source of medicinal plants (Holechek *et al.* 2004). In rangeland habitat where most animal nutritional needs are met, mismanagement has led to deterioration of yield and quality of forage. In other words, a decrease in rangeland areas and an increase in the number of animals has caused significant destruction of rangeland vegetation (Koç *et al.* 2000). As a result, rangeland areas are not able to meet the current roughage demands for livestock. For this reason, understory vegetation in the forest gaps are used as an alternative forage source for animals by local people engaged in animal husbandry.

In general, the rangelands and the forest gaps located at high altitudes are important compensation for the deficit of quality forage in low altitude grazing areas affected by the summer drought. Rangeland vegetation in forest gaps or on the forest's edge can be more productive than common rangelands because it is not subjected to early spring and late autumn grazing (Gökkuş and Koç 1991).

According to the inventory of the General Directorate of Forestry, there are approximately 1.5 million ha of forest gap and forest edge rangelands in Turkey (Avcıoğlu *et al.* 1996). In some countries, forest gaps are used for animal grazing (Sharrow *et al.* 2009, Mancilla-Leytón *et al.* 2012, Hjeljord *et al.* 2014, Osem *et al.* 2015). Productivity and species composition of forest undergrowth may change and proportion of shade resistant plants may increase with differing tree densities (Le Brocque *et al.* 2009). In addition to crude cellulose and crude protein content, forage digestibility (NDF, ADF) has important effects on animal health (Ball *et al.* 2001). The high leaf to stem ratio in the plant is an indicator of forage quality because plant leaves are easier to digest than stems. NDF value is related to the digestibility and quality of the forage (Oba and Allen 1999). As plant maturation progresses, leaf proportion decreases, stem proportion and NDF rate increase (Oba and Allen 1999, Ganskopp and Bohnert 2001), and crude protein rate decreases (Wenick *et al.* 2008). In the spring, which is the green forage period, ADF and NDF ratios are lower than in later periods. For this reason, the forage quality of the spring-grazed vegetation is higher than that of the late-grazed vegetation (Carlassare and Scotton 2003).

Forage quality is important for livestock yield and forage management (Fulgueira *et al.* 2007), and roughage in grazed areas is expected to have high quality. For high quality forage, the protein ratio should be high and the NDF and ADF content should be at appropriate levels. This depends on variety and large quantities of high-quality legume and grass forage crop species in natural rangelands (Amiri and Shariff 2012), as well as appropriate grazing time and grazing distribution.

Animal husbandry is an important source of livelihood in the Eastern Anatolia Region. Sarıkamış, where this study was carried out, has rich forest areas and forest gap rangelands that have the potential to be grazed under an extensive management regime. The forest gaps can help solve the problem of forage shortages during the summer dry period, when forages in open rangelands dry up. However, there is a deficit of important scientific data regarding the productivity and forage quality of these areas, which are mostly used for livestock grazing by local people. The aim of this study was to determine the current situation of forage yield and quality characteristics of understory vegetation in forest gaps under different degrees of tree canopy coverage (open, sparse, and dense) in Scotch pine forests.

METHODS

*Study area and data collection.*The study was carried out in the Sarıkamış district of Kars province between 2006 and 2007, in the understory of Scotch pine forest gaps with an average altitude of 2,240 m a.s.l. (figure 1). The

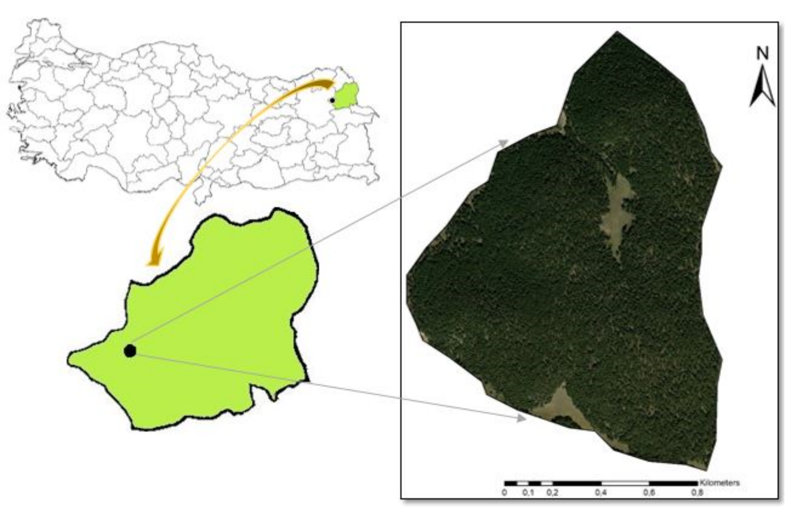

Figure 1. Location of the study area.

Localización del área de estudio.

vegetation in the research area consists of cold resistant species adapted to high altitudes. According to long-term data (1975 - 2006), the average annual temperature is 3.8 °C in Sarıkamış, the average annual precipitation is 601.6 mm and average relative humidity is 70 %. Total precipitation in the first study year was 588 mm and the average temperature was 4.9 °C, while in the second year there were 686 mm of precipitation and the average temperature was 3.5 °C.

The research area was separated into three sites based on tree density; open, sparse and dense. Tree density at the study sites were as follows: (a) an open site with no trees, (b) a sparse site with low Scotch pine tree density (11 - 40 % tree canopy coverage) and (c) a dense site with higher Scotch pine tree density (41 - 70 % coverage, visually estimated). The sparse and dense sites were selected from the same stand of scotch pines (close to each other). The cool-season plants that are adapted to cold climates, members of the *Poaceae* family, are dominant in all sites. The common plant species making up the botanical composition of the study area are presented in table 1. The proportions of plant species in the study area were determined as follows; grass species made up 38.09 %, of the species in the open site, 35.93 % in the sparse site, and 79.01 % in the dense site; legume species 14.21 % in the open site, 29.75 % in the sparse site, and 8.55 % in the dense site; and herb species 47.72 % in the open site, 34.30 % in the sparse site, and 12.44 % in the dense site (Bilgili and Koç 2020).

Soil samples were collected from each site at three different points. The disturbed soil samples were taken from a depth of 0 - 30 cm and transferred to the laboratory in appropriate sample containers. The soil of the research

Table 1. Common plant species of the study área.
Especies de plantas comunes del área de estudio.

	Open site	Sparse site	Dense site
Grasses	*Agropyron intermedium* *Agrostis stolonifera* *Bromus inermis* *Bromus tectorum* *Bromus* sp. *Dactylis glomerata* *Festuca ovina* *Koeleria cristata* *Poa bulbosa* *Poa pratensis*	*Agrostis stolonifera* *Bromus inermis* *Festuca ovina* *Phleum montana* *Poa bulbosa* *Poa pratensis* *Poa* sp.	*Festuca ovina* *Poa bulbosa* *Poa* sp.
Proportion of Grasses (%)	38.09	35.93	79.01
Legumes	*Astragalus* sp. *Coronilla varia* *Lotus corniculatus* *Trifolium pratense* *Trifolium hybridum*	*Trifolium pratense* *Trifolium ambigum* *Trifolium hybridum,* *Trifolium montanum* *Trifolium tricocephalum*	*Trifolium pratense* *Trifolium* sp. *Trifolium tricocephalum*
Proportion of Legumes (%)	14.21	29.75	8.55
Herbs	*Achillea millefolium Alchemilla caucasica* *Descurania sophia* *Galium verum* *Plantago lanceolata* *Plantago atrata* *Polygonum bistorta* *Potentilla recta* *Rumex acetosella* *Taraxacum crepidiforme* *Trogopogon* sp.	*Carex* sp. *Cursiata tavica* *Helycsricum* sp. *Luzula multiflora* *Teucrium* sp.	*Helycsricum* sp.
Proportion of Herbs (%)	47.72	34.30	12.44

*Species considered common are those which represent more than 1 % of the botanical composition. Botanical composition values were calculated over a two-year average.

area was analyzed (Burt 2004) and identified as clay-silt in the open site and silt in the sparse and dense sites. Soil organic matter contents were found to be 4.17 %, 4.54 % and 3.57 % in open, sparse and dense sites, respectively. Soil pH was similar in all experimental sites, with a slightly acidic character. The open site had a nitrogen content of 0.21 %, the sparse site had a nitrogen content of 0.24 %, and the dense site had a nitrogen content of 0.19 %. The open site had a phosphorus content of 28 ppm, while the sparse and dense sites had a phosphorus content of 30.3 ppm. Total lime content was determined as 2.64 % in the open site, 2.95 % in the sparse site and 2.62 % in the dense site.

Plant samples were taken by clipping at the soil surface in ten 0.5 by 0.5 m areas within each site, when the dominant plant species were in their flowering stage. These samples were oven dried at 70 ºC until a constant weight was reached to determine dry matter yield. After weighing, plant samples were ground in order to pass through a 2 mm sieve. The total N content of plant samples was determined by the Kjeldahl method and multiplied by 6.25 to find the crude protein content (Jones 1981). NDF and ADF content were measured using an ANCOM fiber analyzer (ANCOM Technology USA) following the procedure described by Vogel *et al.* (1999). The relative feed value (RFV) was calculated according to the RFV= (88.9 - (0.779 x % ADF)) x (120 / % NDF) equation in accordance with Van Dyke and Anderson (2000).

*Data analysis.*The Analysis of Variance (ANOVA) was used to compare characteristics between the different sites. The analyses were performed using SPSS v. 21.0 statistical software for Windows (SPSS Inc., Chicago, IL). The differences among the means were separated using Tukey's Multiple Range Test. In addition, correlation coefficient analysis between CP, ADF, NDF, RFV, dry matter yield and experimental regions was performed.

RESULTS

Dry matter yields varied between 823 - 1,486 kg ha^{-1} among the sites, a very significant difference (P = 0.008). The dry matter yield at the open site was higher than the other sites. The differences in dry matter production between the sparse and dense sites and between years were not statistically significant. Interaction between year and site was insignificant for dry matter production (table 2).

The highest crude protein content was found at the dense site (12.87 %) and the lowest crude protein content at the open site (9.59 %), showing statistically significant differences (P = 0.003) between the study sites. Crude protein content did not change significantly between the years, and year by site interaction was insignificant (table 3).

The plant samples taken from the dense site had higher NDF content (58.49 %) than those taken from the other sites. The NDF content of the second year's samples was higher (57.95 %) than that of the first year's samples (53.27 %). NDF content did not change significantly between years in open and dense sites but was significantly higher in the second year compared to the first year in the sparse site (figure 2). This difference between years in sparse sites was caused by year-by-site interaction with respect to NDF content.

The highest ADF rate was recorded in the dense site (37.33 %), and the lowest in the sparse site (32.40 %). In terms of ADF content, the open and dense sites were in the same group. The difference between the years was not statistically significant (table 3). For ADF, year and year by site interaction were insignificant.

The relative feed value changed between 95.32 and 112.32 among sites (table 3). According to the two year average, the sparse site had the highest relative feed values (112.32), while the lowest relative feed values (95.32) were recorded in the dense site. The overall average relative feed value was 104.14; 109.83 in the first year and 98.44

Table 2. Dry matter yield in experimental area (kg ha^{-1}).
Rendimiento de materia seca seca en la área experimental (kg ha^{-1}).

	Experimental Sites			
Year	Open site	Sparse Site	Dense Site	Mean
2006	1,265	941	837	1,014
2007	1,486	1,030	823	1,113
Mean	1,376 a	986 b	830 bc	1,064
	Year (P)	0.455 ns		
	Experimental sites (P)	0.008 **		
	Year x Experimental sites (P)	0.761 ns		

P: limiting probabilities in two-factor ANOVA. * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; ns: not significant.
Different letters in each column indicate significant differences (Tukey, $P < 0.05$).

in the second year. This difference between the years and rangeland sites was statistically significant ($P < 0.001$). The sparse site had a higher RFV than the others in the first year, but there were no significant differences among the sites in the second year. This difference between years in sparse sites was caused by year-by-site interaction with respect to RFV (figure 3).

The correlation coefficients as compared between crude protein, ADF, NDF, RFV, dry matter yield and rangeland sites (tree canopy) are presented in table 4. The dry matter yield was negatively correlated ($P < 0.05$) with crude protein content of forage in rangeland sites. There was a strong negative correlation ($P < 0.001$) between RFV, ADF and NDF contents. There was a positive correlation ($P < 0.001$) between crude protein content and tree canopy density of rangeland sites, and a negative correlation ($P < 0.01$) with dry matter yield.

Table 3. Crude protein (%), NDF (%), ADF (%) and RFV of the forage samples.

Proteína cruda (%), FND (%), FAD (%) and VRA de las muestras de forraje.

Experimental Sites	Values of Forage Quality			
	CP	NDF	ADF	RFV
Open site	9.59 b	54.34 b	35.82 a	104.77 ab
Sparse Site	11.16 b	54.02 b	32.40 b	112.32 a
Dense Site	12.87 a	58.49 a	37.33 a	95.32 b
Years				
2006	11.49	53.27 b	34.69	109.83 a
2007	10.93	57.95 a	35.67	98.44 b
Mean	11.21	55.61	35.18	104.14
Year (*P*)	0.411 ns	< 0.001 ***	0.448 ns	< 0.001 ***
Experimental sites (*P*)	0.003 **	0.005 **	0.016 *	< 0.001 ***
Year x Experimental sites (*P*)	0.500 ns	< 0.001 ***	0.217 ns	< 0.001 ***

P: limiting probabilities in two-factor ANOVA. * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; ns: not significant.
Different letters in each column indicate significant differences (Tukey, $P < 0.05$).

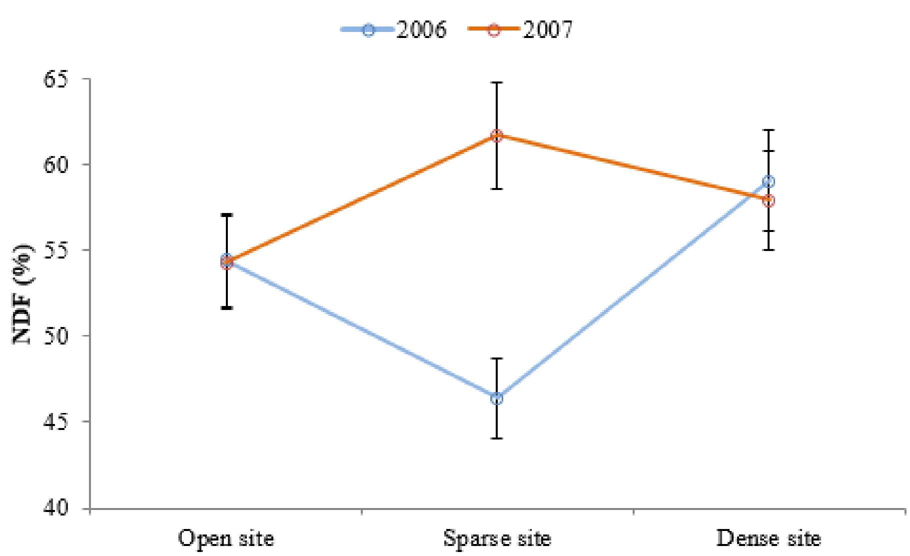

Figure 2. Year x experimental site interaction for forage samples in terms of NDF contents.

Interacción año x sitio experimental para las muestras de forraje en términos de contenido de FDN.

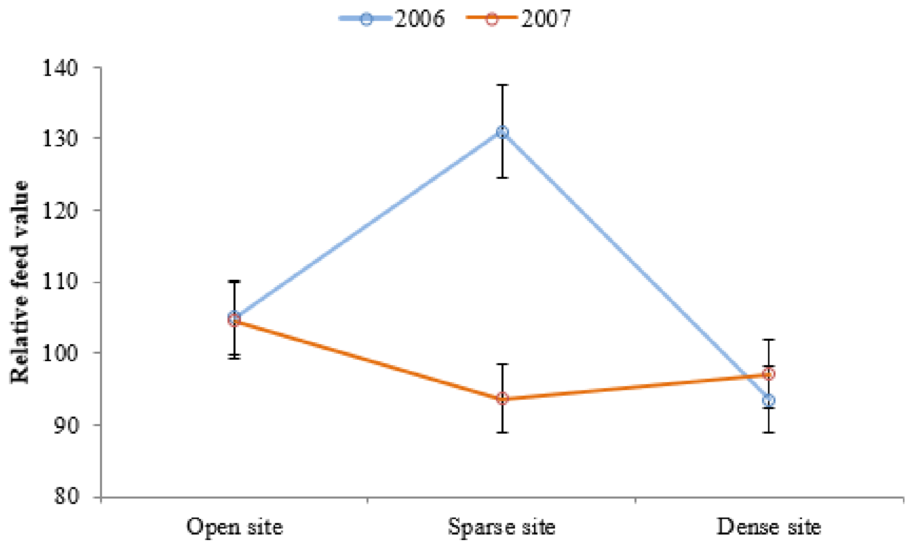

Figure 3. Year x experimental site interaction for forage samples in terms of RFV.

Interacción año x sitio experimental para las muestras de forraje en términos de VRA.

Table 4. Correlation coefficient analysis between crude protein, ADF, NDF, RFV and dry matter yield (tree canopy coverage).

Análisis del coeficiente de correlación entre proteína cruda, FAD, FND, VRA y rendimiento de materia seca (cobertura de las copas de los árboles).

	Crude protein	ADF	NDF	RFV	Dry matter yield
ADF	-0.036	—			
NDF	0.151	0.493	—		
RFV	-0.089	-0.733 ***	-0.948 ***	—	
Dry matter yield	-0.488 *	0.241	-0.070	-0.041	—
Experimental sites (tree canopy coverage)	0.667 ***	0.171	0.313	-0.273	-0.612 **

P: limiting probabilities in two-factor ANOVA. * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; ns: $P > 0.05$.

DISCUSSION

Our findings reveal that dry matter yield decreased with increasing tree density in the experimental area. Similar results were also recorded by Norton *et al.* (1991). They reported that dry matter production tended to show a decreasing trend in line with increased tree density. Similarly, Smit (2005) recorded that the herbaceous layer, in terms of dry matter yield, showed a positive response to the tree thinning treatments. Trees prevent sunlight from reaching plants due to shading effects, and accordingly, biomass production decreases (Paciullo *et al.* 2008). Generally, it was reported that biomass production decreased in forest understory vegetation in line with increasing shading effects (Kyriazopoulos *et al.* 2006).

The crude protein content increased with increasing tree density in research sites (table 4). In addition to differences in plant composition among the sites, irregular growth stages can also contribute to differences in crude protein content. Consequently, higher crude protein content was recorded in the sites with trees because the shading effect may decrease structural carbohydrate accumulation in the tissue compared to the open site for plant samples taken at the same time. Results of studies by Oba and Allen (1999), Ganskopp and Bohnert (2001), Wenick *et al.* (2008) and Pedreira *et al.* (2013) support our findings, stating that the rate of crude protein decreases as the maturation of plants progresses due to increased structural carbohydrate in the tissue. Similarly, Lin *et al.* (2001) and Pandey *et al.* (2011) found that the rate of crude protein in plants grown in shade is higher, in accordance with these results.

The study of Ganskopp and Bohnert (2001) stated that a crude protein ratio of 7.5 % can be accepted as sufficient for the needs of many wild and domestic herbivores. Therefore, the crude protein content in all experimental sites within the present study can be considered adequate for consumption by livestock.

The highest NDF and ADF content were found at the dense site, and the lowest at the sparse site. This situation is compatible with the fact that the highest ADF rate occurred in the dense section, according to the values obtained in the research. Similar results were obtained by Lin *et al.* (2001) and Ladyman *et al.* (2003).

The occurrence of similar ADF values in open and dense sites may be related to the significant proportion of grasses in the botanical composition. The presence of low NDF in forage samples taken from open and sparse sites may be related to the species composition. Many researchers (Darambazar *et al.* 2013) have noted that grasses contain higher NDF than legumes, which supports these findings. With respect to NDF content, similar results were also recorded by Kaya *et al.* (2004) in the region's rangelands.

The experimental site interactions for these parameters resulted in differences in NDF and RFV content between years in the sparse sites. The high rate of NDF, which in the second year also affected RFV in the sparse site, may be related to changes in botanical composition originating from climatic differences or changes in growth trends in plants due to wild herbivore grazing. As expressed by Tesk *et al.* (2018), climatic differences and grazing affect the temporal trend of NDF content in forage stands. Also, ADF and NDF contents are expected to be high in plants grown in the shade. Similar results were obtained by Lin *et al.* (2001) and Ladyman *et al.* (2003), which also supports this interpretation. As a result, it can be assumed that the NDF content of forage in the research area is affected more by species composition than by shading. In reality, grazing (Wenick *et al.* 2008) and light level (Ladyman *et al.* 2003) had no significant effect on NDF and ADF content.

The highest relative feed values were found at the sparse site and the lowest at the dense site. Relative feed values were calculated using NDF and ADF contents. Therefore, factors affecting NDF and ADF content impact relative feed values. According to a classification of relative feed values defined by Redfearn *et al.* (2006), the open and sparse sites were in the 2nd quality class, and dense sites were in the 3rd quality class. These differences among the sites were mainly due to changes in botanical composition and differences in growth stage caused by radiation interception by differing tree coverage.

The data we collected for our study in 2006 and 2007, more than 15 years ago, remains pertinent today. Because of the location of the study area, no change in climate variables was observed in the last 15 years. Long-term averages (1959 - 2021) show that Sarıkamış has an annual temperature of 3.8 °C, 633.6 mm of annual precipitation, and average relative humidity of 70.7 %. There was no discernible difference between these values and the average climate values of the research years. Seasonal changes in temperature and water availability may affect plants (Zeppel *et al.* 2014). However, as there was no significant change in climatic data during the active growth period for plants, it seems that climate change is not impacting forage yields in the study area. The results of the present study are applicable not only to Sarıkamış districts, but also to forests and rangeland in highland zones with similar ecological characteristics.

CONCLUSIONS

In the experimental area, differences in tree density caused some significant variations in forage yield and quality among the sites. In comparison to open sites, the dry matter yield was generally lower in sparse sites. It can be inferred that the sparse sites had better forage quality than the other sites. However, with sustainable grazing management, the understory vegetation in the forest gap can be utilized, particularly in open and sparse tree canopies. During the region's grazing season, the understory produces a sizable amount of forage of sustainable quality and may help to solve the forage shortage issue. When the summer dry period causes the forage areas in open grazing lands to dry out, these areas can be especially suitable for grazing. However, considering that animal husbandry is the most significant industry in areas with similar ecologies, it is important to assess sustainable management plans, conduct additional research, take into account seasonal variations in forage quality, and integrate the findings into grazing management systems.

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