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Determination of the factors affecting utilization rate of Eastern Anatolian semiarid public rangelands in Turkey

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Abstract

Rangelands are important natural resources for the nations with a various measurable and immeasurable outputs such as forage for farm animals, biological diversity, soil and water conservation and ecosystem functions. However, unconscious exploitation has resulted in weakening, deterioration and exhaustion of these natural resources in time. In achieving an effective, sustainable use at a minimum environmental cost without foregoing economic and social development, policy measures towards conscious utilization, conservation and restoration of these resources are of vital importance. Furthermore, user-friendly, robust policy measures require correct scientific information on the actual utilization of rangelands. The effects of various natural and human induced factors on the rangeland forage yield and its utilization rate were researched in this study. Data were collected from the rangelands of 11 villages in five districts of Erzurum province, Turkey. Descriptive statistics and mixed effect panel regression models were used in data analysis. According to the results it was concluded that 1) because of heavy grazing pressure versus low forage production, high-altitude sites, east and southwest slopes should specifically be given the priority in rangeland rehabilitation studies, 2) drought resistant species should be preferred for the overseeding practices due to the xeric nature of southerly slopes, 3) to avoid excessive exploitation and to realize balanced utilization in all rangeland sites, grazing plans should be developed and strictly followed by each village authority, and 4) Heavy grazing pressure on rangelands gets even worse in drought seasons. Therefore, rangelands should be relatively lightly utilized in such seasons not to cause herbage yield losses and other unwanted outcomes in subsequent years.

Keywords: Conscious utilization, Sustainable use, Natural and human induced factors, Mixed effect panel regression

Introduction

Eastern Anatolia region in Turkey has favourable conditions for animal production due to its vast meadow and rangeland asset. Rangeland dependent extensive animal production has been a way of livelihood generation in the region for centuries. The grazing farm animals in the region include indigenous breeds and their crosses with commercial ones, which are well adapted to regional geo-climatic conditions and utilize the rangeland more efficiently. The proportion of the purebred animals is low in the region. In Turkey, rangelands are commonly used vegetation covers, whose rights are left to the legal entity of each village with certain demarcation by the laws. Village flocks and herds graze separately under the supervision of herders or shepherds with daily excursions starting with sunrise and ending with the sunset (Kara et al., 2014).

The basis of the developing grazing plans, indicating how long and how many animals to be kept in rangelands, is to determine or estimate quantity of the forage to be grazed. For sustainable use it is of vital importance to know how much of the forage to be grazed without damaging the rangelands. A grazed, trampled or destroyed part of rangeland forage has been reported to be a measure of utilization for given rangeland, and its share in total production is described as rangeland utilization rate. It is suggested that utilization rates of rangelands should be justified according to rangeland condition. For example, utilization rates of 20–30% for alpine tundra, 35–

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45% for western mountainous rangelands, 40–50% for short grass prairies, 45–60% for tallgrass prairies, and 45–55% for cool season grasslands have been recommended (Vallentine, 1990, cited in Gökkuş and Koç, 2001). Accordingly, 25–30% and 30–40% of utilization rates were suggested for poor and moderate condition rangelands and 50–55% of utilization rate was recommended for very good condition rangelands (Gökkuş and Koç, 2001).

Rangeland forage and its utilized proportion, namely the utilization rate or factor are all affected by a number of natural (e.g. geographic aspect) and human induced factors (e.g. stocking rate). In Turkey, a considerable number of invaluable studies were conducted on rangelands. Yet mainly botanical composition was handled and the studies seeking to determine the forage production were limited. In some related studies, production potential and/or utilization degree of the different rangeland sites (e.g. hills, hillsides) was indirectly categorized (i.e. poor, moderate, heavy, excessive, etc.) considering some indicators (e.g. canopy cover, rangeland condition, proportion of some certain plant species). Utilization rate and the factors effective on it were out of their scope and/or not handled in a comprehensive manner. In their study, Kara et al. (2019) estimated the rangeland dry forage yield and utilization rate but they did not mention how they were affected under various human induced and natural rangeland related factors. The present paper aimed to answer these questions using the same study data. To this end, rangeland forage production and its utilization rate were examined under the effect of various rangeland properties, such as altitude, distance to village, stocking rate, rangeland condition, and geographical aspects. Study findings will be expected to provide valuable information for the future rangeland and animal related studies, not only in Turkey but also in countries sharing similar agroecological conditions, cultural and historical backgrounds of rangeland use pattern.

Materials and Methods

Materials

The primary material of this study was obtained from the vegetation surveys and the forage harvested from cages and random quadrats from the 12 permanent representative sites in the rangelands of 11 villages in Erzurum province, Turkey. In addition, the relevant records of the official institutions related to the study were used as secondary material.

Study Area

The study area covers Erzurum province that reflects the main characteristics of the Eastern Anatolia region of Turkey regarding geography, climate, production type, and pattern (Figure 1). This region is known for its suitability for livestock production due to its one-third share in total rangeland asset of Turkey. That is, the rangelands have determined the way of livelihood generation and extensive livestock production system has prevailed for centuries in the region. It has very rugged geography and very harsh terrestrial climate and is located within the 39 54’ 31” northern latitudes and 41 16’ 37” eastern longitudes. Altitude is ranging from 2000 m asl in plateaus to 3000 m asl and higher in the mountains and can be as low as 1000-1100 m asl in valley floors and 1500 – 1800 m asl in plains. Despite the existence of plain areas, the topography is mostly fragmented, and the dominant vegetation is steppe grasses (60%) as woodland is scarce (%6). Winters are long and harsh, and summers are short and hot. In a long term (1975 to 2006), the average number of frozen days and the days with snow cover are 154 and 113 days, respectively, while annual average temperature and total precipitation are 5.5 °C and 453.3, respectively (TÜMAS, 2013). Annual precipitation was 436.6 and 317.8 mm for the study years of 2007 and 2008, and seasonal precipitation for April-October period was 308.5 and 234.1 mm respectively. Thus, the year 2008 was distinctively drought with negative balances of 74.4 and 118.8 mm corresponding annual and seasonal precipitations respectively.

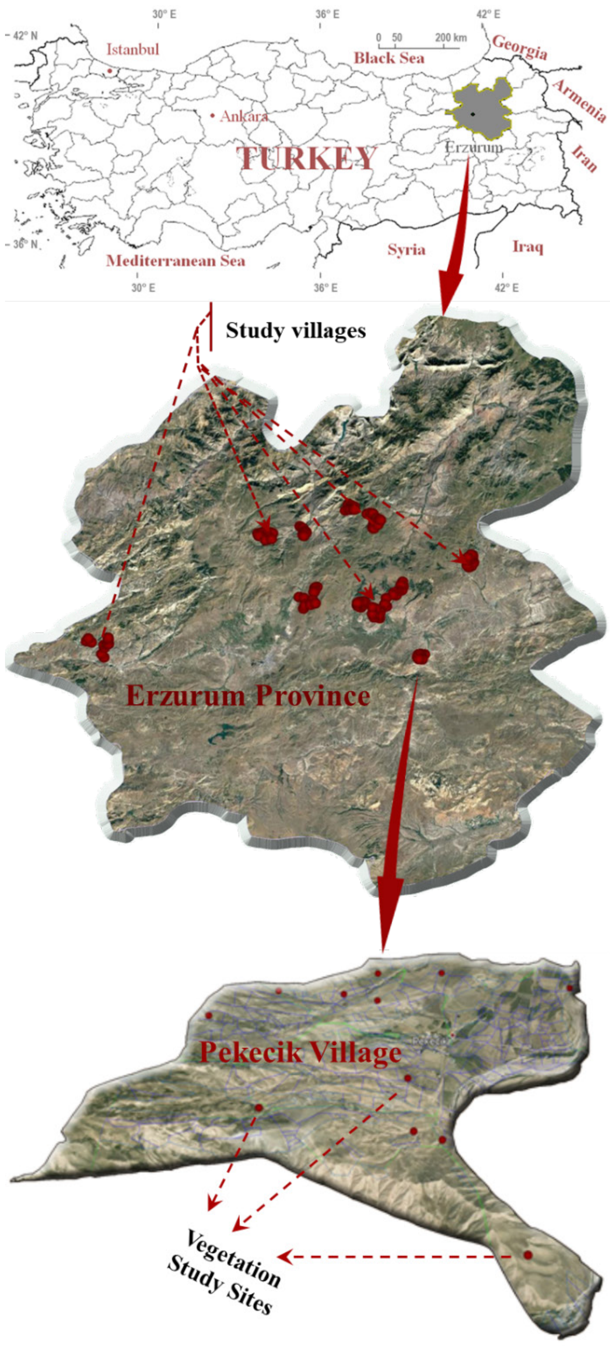

Figure 1. The study area in Turkey
Source: Adapted from Kara et al. (2019)

Selection of the villages

Study villages were selected with a special emphasis to represent over the surrounding area, to ensure that they were free from nomadic movements and boundary problems, and that their rangeland demarcation and allocation studies have been completed. Thus, from Aşkale, Narman, Pasinler, Köprüköy, Horasan, and Tortum districts in a total of 11 villages were selected for the study. The distance among the villages varied from a minimum of 7.9 km to a maximum of 126.5 km. The villages share more or less similar production patterns but differ from each other regarding the acreage of rangelands and the total animal asset. As seen in Table 2, animal asset in villages fluctuates over years which could be explained with the change in number of inhabitants and the policy measures. That is, migration to urban areas especially from mountain villages decrease the number of inhabitants (farmers) and, in turn, number of grazing animals in time. On the other hand, number of animals may increase due to policy measures towards encouraging animal production which conversely cause increased stocking rates in the same villages. So, the stocking rate differences among the villages and within the same village in time are an expected phenomenon.

As mentioned earlier, village rangelands in Turkey are in common use and grazing is not managed according to the herbage production and rainfall. In a private farm with a private rangeland property, farmer considers the optimum stocking rate for better use of his or her rangeland. In common use, however, rangelands are used in an opportunistic manner by ignoring their capacity.

Vegetation studies

The vegetation studies were performed in 2006 to characterize the rangeland vegetation and calculate the condition of the rangelands. Vegetation was studied using modified wheel point method according to Koç and Çakal (2004) at representative 12 permanent sites in each study village with four replications along the 100 m transect lines in main directions (Figure 2 and 3).

Table 1. Rangeland, animal asset (in animal units), and rangeland stocking rates of the study villages

Villages in the Study Area	Rangeland Asset[1] (ha) (a)	Animal Asset (AU)[1] 2007 (b)	Animal Asset (AU)[1] 2008 (c)	Stocking Rate ($AU.ha^{-1}$) 2007 ($d=b\times a^{-1}$)	Stocking Rate ($AU.ha^{-1}$) 2008 ($e=c\times a^{-1}$)
Köşk	7349	1160	1418	0.158	0.193
Taşağıl	1177	518	600	0.440	0.510
Yeniköy	576	674	606	1.170	1.052
Yayladağ	452	538	510	1.191	1.128
Demirdöven	430	1159	832	2.690	1.935
Pekecik	217	111	239	0.512	1.101
Gerek	2138	734	941	0.340	0.440
Şehitler	883	716	718	0.811	0.813
Esendurak	191	79	140	0.412	0.733
Tipili	1548	330	442	0.213	0.286
İncedere	595	245	327	0.412	0.549
Total	15556	6264	6772	0.759	0.795

Figure 2. Vegetation study using modified wheel point method[2]

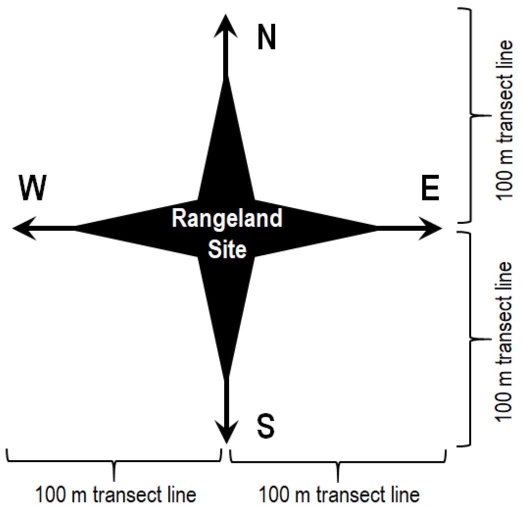

Figure 3. Vegetation reads in rangeland sites

[1]Obtained from the official records of the directorates of agriculture operating in the study area

[2]Wheel-point method (WPM) of Griffin (1989) is based on a rimless wheel apparatus. It is rolled along the transect line on its spokes by the aid of a handle attached to it. A counter on the apparatus counts the number of revolutions the wheel has made. Two opposite spokes are tapered, and the ends of the rest are covered with rubber buffers to make rolling easier over the ground. This method was modified by replacing the original 5 cm diameter measurement unit with the rings holding an area of 3.14 cm2 as in loop method in order to make it efficient in the areas exposed to erosion (Çakal et al., 2012). In modified version of this method, the rimless wheel has a radius of 31.85 cm to make 200 cm perimeter allowing two reads with a-one-meter intervals. Thus, 50-wheel revolutions sum up 100 reads in a 100 m-line transect.

Calculation of rangeland condition

The rangeland condition is described as the comparison of the existing state of the rangeland vegetation cover at a given site with the best possible state under the similar prevailing conditions (Koç et al., 2003). By employing the vegetation study data from each site in every studied village, the rangeland condition was calculated according to the Rangeland

Quality Degrees, explained by De Vries et al. (1951), cited in Koç et al. (2003), using Equation 1.

$$R_{Condition} = \sum P_i \times QS_i \qquad [1]$$

Where P_i denotes the relative abundance of i^{th} species, calculated as the proportion of individuals of i^{th} species to the total number of individuals coincided at the studied site, and QS_i symbolizes the quality rating of the i^{th} species (Kara, 2019). It expresses the values given to each species according to the grazing and productivity attributes of the coincided species such as productivity, post-grazing regeneration ability, and palatability and varies between –1 and 10. In this qualification, a toxic plant receives –1 point and a score between 1 and 10 indicates the degree of other desirable properties (Koç et al., 2003; Altın, 2001; Koç and Gökkuş, 1996). In this method, vegetation cover is accepted as the product of climate and soil, as such that the information on climax vegetation is not needed. In this method, the rangeland condition, i.e., rangeland quality degree, varies between 1 and 10 and is classified as 1–2: very poor, 3–4: poor, 5–6: moderate, 7–8: good, and 9–10: very good condition (Koç et al., 2003).

Calculation of the rangeland utilization rate

Rangeland utilization rate is the percentage of forage grazed or removed by animals out of the total forage produced by rangeland to fulfil the condition not to cause rangeland degradation (Gökkuş and Koç, 2001). 132 cages (one cage at each of 12 permanent rangeland sites in each of 11 study villages) with 1 m height and 1 m × 1 m floor area were placed in the rangelands of study villages before the grazing season of 2007. Lost and disassembled cages were fixed and completed to 132 before the grazing season in 2008. Forage under the cages was clipped to the ground at the end of the grazing seasons to estimate the seasonal rangeland forage production. Unavailable observations due to the lost or disassembled cages were treated as missing data.

In estimating the forage removed by grazing animals, rangeland stubble was sampled by clipping to the ground using four random quadrats (equivalent to cage floor area, e.g. four quadrats = 1.0 m^2) in surrounding areas of each cage at the end of the grazing seasons. The harvest weights of the forage and stubble and their dry weights after dehydration at 70 °C for 48 h in an oven were recorded.

As also reported elsewhere (Kara et al. 2019), rangeland utilization rate was calculated based on the weight of the stubble left after grazing. To this purpose, first, the utilized rangeland forage was calculated by subtracting stubble from the forage yield and converted to per hectare yield. Finally, the utilization rate was calculated by dividing the forage utilized by the total forage yield (Gökkuş and Koç, 2001).

Data analysis

As mean averages rangeland forage production and utilization rate were presented elsewhere. In this paper were examined the effects of some natural and human induced factors on the rangeland dry forage yield and utilization rate. The variables of interest are detailed in Table 3. Of all the variables, stocking rate was calculated using the secondary data obtained from the provincial and district directorates of agriculture operating in the study area while the rest was obtained from the vegetation studies.

It is very easy to clarify the effect of independent variables on dependent variables when linear estimators, i.e., regression coefficients, are used. However, in order to control the heterogeneity due to the entities considered in the study, panel data regression is suggested for unbiased results (Baltagi, 2005). In the present study, the data were collected from a considerably wider area, which covers the rangelands of 11 villages. The distance from the studied rangeland sites to the village varies from 360 m to 6790 m as the villages are apart from each other from a minimum of 7.9 km to a maximum of 126.5 km. Thus, due to the inevitable heterogeneity the panel data regression was suitable for data analysis.

The most prominent techniques used to analyse panel data are fixed effect (FE) and random effect (RE) models.

Table 2. The details of the study variables

Variable	Explanation
DRY Forage Yield	Rangeland dry forage yield (kg.ha^{-1})
Utilization Rate	Utilization rate of the studied rangeland site (%)
Rangeland Condition	Rangeland condition of the rangeland sites (as the fragment of 10)
Altitude	Altitude of the studied rangeland sites (m)
Distance	The distance of the studied rangeland site from the village (m)
Stocking Rate	Stocking rate at village rangelands (AU per hectare)
Bare Ground	Bare ground percentage of the studied rangeland sites (%)
Legumes	Number of legume species in the botanical composition of the rangeland sites (in number)
Grasses	Number of grass species in the botanical composition of the rangeland sites (in number)
Forbs	The number of forb species in the botanical composition of the rangeland sites (in number)
Species Richness	Number of herbaceous species encountered at the studied rangeland sites (in number)
Species Abundance	Number of individuals per species encountered at the studied rangeland sites (in number)
Grazing Season	Grazing season (2007= the first year; 2008=the second year)
Geographic Aspect	Geographical aspect of the studied rangeland sites (1 = Flat; 2 = North; 3=South; 4=East; 5=West; 24= Northeast; 25=Northwest; 34=Southeast; 35=Southwest)

FE explores the relationship between predictor and outcome variables within an entity (country, person, company, etc., herein, permanent rangeland sites). Each entity has its own individual characteristics that may or may not influence the predictor variables. Unlike the FE model, the variation across entities is assumed to be random and uncorrelated with the independent variables in RE model (Torres-Reyna, 2007). Yet, in case RE model is appropriate as in the present study, the mixed linear model is suggested to incorporate both fixed and random variables (Cameron and Trivedi, 2010; Adkins and Hill, 2011). For that reason, the mixed linear model is employed in data analysis as descriptive statistics methods were also employed to summarize the variables.

Table 3. Geographical aspects of the studied rangeland sites

Geographical Aspects	Frequency	%
Flat	18	13.6
North	20	15.2
South	34	25.8
East	13	9.8
West	9	6.8
Northeast	14	10.6
Northwest	7	5.3
Southeast	14	10.6
Southwest	3	2.3
Total	132	100.0

Mixed effect linear regression model can be written in the form of Equation 2 (Torres-Reyna, 2007; Cameron and Trivedi, 2010; Gujarati, 2011).

$$Y_{it} = \alpha + \beta_1 X_{1it} + \beta_2 X_{2it} + \cdots + \beta_k X_{kit} + u_{it} + \varepsilon_{it} \quad [2]$$

Y_{it} represents a dependent variable
X_{it} represents explanatory (independent) variables
α represents intercept
β_1 to β_k represent slope coefficients
k represents k^{th} coefficient
i represents i^{th} individual
t represents the time
u represents between entity/individual error term
$\boldsymbol{\varepsilon}$ represents within entity/individual error term

In the regression models, the categorical variables were represented by dummy variables, in number less by one than the classification of the qualitative variable (Gujarati, 2011). In this study, the variable of the geographical aspects had nine categories including flat (zero) aspect. Thus, it was represented by eight dummies and four of them were for main directions and four were for intermediate directions. Since the dummy variable for flat aspect was not included in the regression model, the coefficients of other dummy variables should be interpreted in relation to the reference category (flat aspect) as the coefficients of other continuous independent variables represent the marginal change in the dependent variables as a result of one-unit change in the continuous dependent variable of interest at *ceteris paribus*.

The rangeland dry forage yield and its utilization rates were considered to be the functions of the continuous and discrete variables given in Table 3. Skewness-Kurtosis test and graph methods were used to control the normality of the residuals of the model (Gujarati, 1995; Torres-Reyna, 2007; Park, 2008; Gujarati, 2011; Adkins and Hill, 2011). The data analysis was performed using Stata SE 14.2 software package (StataCorp, 2015).

The normality assumption was failed according to the Skewness-Kurtosis test. However, according to the normal probability plot distribution of the residuals obtained and the fact that the normality test may determine statistically significant yet negligible deviations from normality (Anonymous, 2013), the deviations from the normal line can be omitted since they have no real effect on the linear regression tests. As a matter of fact, it becomes more difficult to meet the normality assumption with a larger sample size, since even small differences are detected. Therefore, it can be accepted that normality may be a problem when the sample size is small (Lumley et al., 2002). Due to using short panel of two years, cross-sectional dependence or contemporaneous correlation and serial correlations were not tested in our study as these need to be addressed only in macro panels with long time series data (Baltagi, 2005; Torres-Reyna, 2007). However, heteroskedasticity in the error term is reported to be one of the commonly encountered problems in cross sectional data and Robust Standard Errors procedure is suggested to cure heteroskedasticity problem (Torres-Reyna, 2007; Gujarati, 2011; Adkins and Hill, 2011). Accordingly, I employed clustered robust standard errors procedure in regression analysis since the studied sites were clustered geographically (Table 3).

Results

Rangeland properties

Some of the rangeland properties based on the vegetation data collected from the 132 sites in the rangelands of 11 villages in the study area are presented in Table 4. Because mentioned elsewhere (Kara et al., 2015), vegetation study results, e.g. the species encountered, and their family groups were not given here to avoid repetition. The rangeland condition of the study area falls within the poor to moderate condition classes, making an average of 3.23 score in fraction of 10 (Table 4).

Rangeland dry forage yield

According to mixed effect panel data regression model (Table 5), grazing season (year) and stocking rate had significant negative effects (p<0.01) on rangeland dry forage yield. The rangeland condition, distance to village, species richness, number of species for legumes and grasses, bare ground and altitude × distance interaction did not significantly affect the rangeland dry forage yield. The model suggests that shifting from the first to the second year of the study, dry forage yield decreases 459 kg per hectare and a one-unit increment in stocking rate likely causes 354 kg decrease in dry forage yield per hectare. As for geographical directions, northwest slopes yielded very significantly (p<0.01) and east slopes yielded significantly (p<0.05) less dry forage per hectare in contrast to flat (zero) aspect, i.e. northwest slopes yielded 603 kg and east slopes yielded 204 kg less in contrast to reference flat aspect (Table 5). Similarly, southwest slopes also yielded less than the reference aspect, but the difference was only marginally significant (p<0.1). Moreover, northeast and southeast slopes yielded more as north, south and west slopes yielded less dry forage than reference flat aspect (Figure 3a), yet the differences with the reference were not significant (p>0.05).

Table 4. Some of the rangeland properties reported for the studied sites in village rangelands

Variables	Observations	Minimum	Maximum	Average	St. Deviation
Altitude (m)	131	1593	2847	2088.27	269.48
Distance to Village (m)	129	360	6790	2354	1374.10
Bare Ground (%)	132	5.00	49.00	25.61	9.57
Species Richness	132	8	28	19.09	4.12
Legumes	*132*	*0*	*7*	*3.29*	*1.66*
Grasses	*132*	*1*	*7*	*3.86*	*1.18*
Forbs	*132*	*3*	*19*	*11.95*	*3.07*
Species Abundance	132	51	95	74.39	9.57
Legumes	132	0	43	14.26	8.85
Grasses	132	6	40	20.93	6.26
Forbs	132	11	63	39.20	9.78
Rangeland Condition	132	1.89	5.06	3.23	0.66
Stocking Rate	22	0,16	2,69	0,78	0,61
Rangeland dry forage yield	193	130	7200	1012,3	826,1
Rangeland dry stubble yield	193	11	2036	310,8	308,1
Utilized rangeland forage	193	0	6401	701,6	681,1
Rangeland utilization rate	193	0	96	69,1	19,7

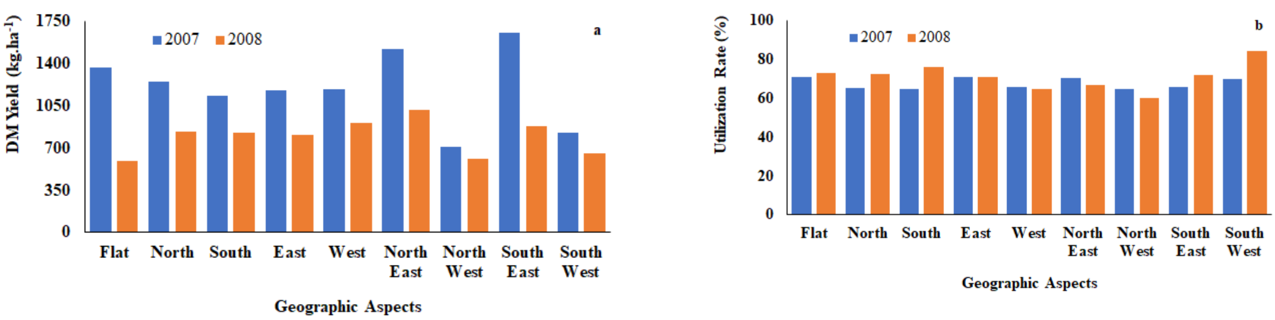

Figure 3. Rangeland forage yields (a) and utilization rates (b) by the aspects of studied site

Table 5. The results of mixed effect regression analysis for the factors affecting rangeland dry forage yield

Independent Variables	Coefficient	Robust Std. Err.	z	P>|z|
Grazing Season (Year)	-458,519	90,426	-5,070	0,000
Altitude	-0,745	0,579	-1,290	0,198
Rangeland Condition	256,453	260,026	0,990	0,324
Distance to Village	-0,254	0,308	-0,830	0,409
Altitude × Distance to Village	0,000	0,000	0,770	0,438
Stocking Rate	-350,089	115,485	-3,030	0,002
Bare Ground	-2,805	8,152	-0,340	0,731
Species Richness	34,552	24,612	1,400	0,160
Legumes	-136,498	121,796	-1,120	0,262
Grasses	14,755	62,108	0,240	0,812
Geographic Aspects				
North	-18,854	84,716	-0,220	0,824
South	-44,697	73,967	-0,600	0,546
East	-238,949	93,796	-2,550	0,011
West	-17,698	41,146	-0,430	0,667
Northeast	153,562	117,417	1,310	0,191
Northwest	-601,069	83,423	-7,210	0,000
Southeast	142,552	99,852	1,430	0,153
Southwest	-265,540	156,251	-1,700	0,089
Constant	922352,300	181006,200	5,100	0,000
Random-effects Parameters	Estimate	Robust Std.Err.		
SiteNo: Identity				
Var (Constant)	301631.4	236570.8		
Var (Residual)	256724.4	46014.4		

Log pseudo likelihood: -1505.044; Obs.=189; Group variable: SiteNo, Groups:110 (Std. Err. Adjusted for 9 clusters in Geographic Aspects)

Rangeland utilization rate

In mixed effect regression analysis, dry forage yield and its squared form were included into the model as independent variables because of a quadratic relationship detected between dry forage yield and its utilization rate. According to the results, grazing season and altitude had significant positive effects on utilization rate ($p<0.05$) while rangeland condition and stocking rate were positively but only marginally effective ($p<0.1$) on utilization rate. The results suggest that a 1000 m increment in altitude brings about 33% more utilization and a one-unit increments in rangeland condition (one out of 10, e.g. an increase of 10%) and stocking rate (one-unit AU per hectare) causes 2% and 10.6% more utilizations respectively at *ceteris paribus*, considering the two-year averages.

As for the qualitative variable the geographic aspects, east and southwest slopes were utilized very significantly ($p<0.01$) more compared to reference flat aspect. Again, north, south and southeast slopes were utilized more as northwest, west, northeast and northwest slopes were less utilized in respective order compared to reference aspect, but the differences were not meaningful ($p>0.10$).

Discussion

The main focus of this study was the determination of factors affecting rangeland forage production and its utilization rate This was tackled by considering the effects of some natural (e.g. geographic aspects) and human induced factors (i.e. stocking rate). Although type, depth and nutrient content of soils, sloping degree, prevailing wind directions, evapotranspiration are all affecting rangeland biomass and may also directly or indirectly affect rangeland utilization rate, for the ease and simplicity of the study these all factors were not handled, and they were kept beyond the scope of this study and have been left as the subjects for further studies. Moreover, the findings related to rangeland vegetation and condition were not touched in detail in this study because a number of previously conducted studies in the region revealed more or less similar patterns (Erkovan et al., 2003; Öztaş et al. 2003; Dumlu et al., 2011; Avağ et al., 2012; Çomaklı et al. 2012; Çakal, 2016).

In forage production model (Table 5), very significant negative sign of the coefficient of ‘grazing season’ variable indicated a low yield in the second year. This can be explained with the negative balances of annual (74.4 mm, 27%) and seasonal (118.8 mm, 24%) precipitations in the same year.

Since moisture plays a key role in the composition, structure, and density of the plant communities in the areas with less than 600 mm annual precipitation (Kutiel and Lavee, 1999, cited in Maren et al., 2015), in such places including the study area rangeland forage production is mainly determined by rainfall (Duan et al., 2017). In line with our findings, a significant effect of the precipitation on rangeland forage was also reported by O’Connor and Rouxt (1995), Khumalo and Holechek, (2005), Koç (2001) and Browning et al. (2012).

Table 6. The results of mixed effect regression analysis for the factors affecting rangeland utilization rate

Independent Variables	Coefficient	Robust Std. Err.	z	P>|z|
Grazing Season (Year)	6,247	2,606	2,400	0,017
Altitude	0,033	0,014	2,320	0,020
Rangeland Condition	2,011	1,175	1,710	0,087
Distance to Village	0,008	0,012	0,720	0,475
Altitude × Distance to village	0,000	0,000	-1,210	0,225
Dry Forage Yield	0,003	0,002	1,140	0,255
Dry Forage Yield Squared	0,000	0,000	-0,340	0,732
Stocking Rate	10,636	5,875	1,810	0,070
Bare Ground	0,297	0,185	1,610	0,108
Species Richness	-0,362	0,668	-0,540	0,588
Legumes	0,221	1,347	0,160	0,870
Grasses	0,446	2,163	0,210	0,837
Geographic Aspects				
North	3,085	2,183	1,410	0,158
South	1,845	1,267	1,460	0,145
East	6,708	2,267	2,960	0,003
West	-0,893	2,422	-0,370	0,713
Northeast	-0,557	1,477	-0,380	0,706
Northwest	-4,186	4,283	-0,980	0,328
Southeast	0,152	1,173	0,130	0,897
Southwest	10,986	1,386	7,930	0,000
Constant	-12552,470	5252,536	-2,390	0,017
Random-effects Parameters	Estimate	Robust Std.Err.		
SiteNo: Identity				
Var (Constant)	23.915	29.824		
Var (Residual)	293.532	43.996		

Log pseudo likelihood: -812.30; Obs.=189; Group variable: SiteNo, Groups:110, (Std. Err. Adjusted for 9 clusters in Geographic Aspects)

In utilization rate model, on the other hand (Table 6) significant and positive signed coefficient of the 'grazing season' variable means that utilization rate increased significantly in the relatively drought second year of the study, suggesting that heavy grazing problem worsens in the years of low forage yield, which is also obvious in Figure 3b. Whereas, light or moderate grazing is suggested in drought seasons not to cause yield losses in subsequent years (Pieper and Donart, 1975. Ganskopp and Bedell, 1981).

The effect of forage yield and its squared (quadratic) form on utilization rate were not significant ($p>0.05$).As a priori and so reported by Okatan et al. (1999), I would expect less herbage yield at higher altitudes due to shorter vegetation period resulting from low temperatures. In the dry forage yield model, the negative sign of 'altitude' variable fulfils this expectation, but it is not significant ($p>0.05$). Özgür et al. (2017), in line with present findings, reported no significant differences between the dry forage yields at different altitudes. However, non-significant less herbage yield at higher altitudes significantly resulted in higher utilization rates ($p<0.05$). According to the utilization rate model (Table 6), 1000 m increment in altitude causes 33% increase in utilization rate at *ceteris paribus*. It may bring one's mind that the higher the altitude the higher the utilization rate, suggested by the present study findings, contradicts with the low DM intake at higher elevations reported by Christen et al. (1996). However, this is not contradictory and could be explained with lower herbage production at higher elevations due to the reasons explained before e.g. cooler temperature and shorter vegetation period. Accordingly, the negative signed coefficient of 'altitude' variable in the dry forage yield model refers to low herbage production at higher altitudes, although not significant (Table 5). Again, remembering higher utilization rates in cases of herbage scarcity may be helpful. Nevertheless, Tamartash (2012) reported no relationship between livestock utilization and elevation.

The effect of distance to village (from the rangeland sites) and distance × altitude interaction were not significant in any of the two models.

Although grazing or carrying capacity calculations were based on the available forage amount (Gökkuş and Koç, 2001), Danckwerts and Aucamp (1984) reported that the range condition has a significant effect on grazing capacity. However, despite the positive signed coefficient, the effect of range condition on dry forage yield was not significant in the present study. In utilization rate model, though only marginally significant ($p<0.1$), rangeland condition had a positive effect on utilization rate, which could be explained with selective grazing of animals.

On the other hand, the effects of stocking rate on rangeland dry forage yield and utilization rate were found very significant ($p<0.01$) and only marginally significant ($p<0.1$) respectively. It may come to mind that there is no sense to include stocking rate variable into the dry forage yield model due to the cages used to save the herbage from grazing animals. However, it would be better to remember that the current stocking rates provide an indication of the past grazing pressure. For that reason, very significant negative effect of stocking rates in the dry forage yield model could be explained by the degradation of the rangelands due to heavy grazing pressure prevailing over decades.

Conversely, the utilization rate model, reflects the effect of current stocking rates on the utilization rate since it considers the readily grazed or removed forage amounts. This model suggests that a one-unit increment in stocking rate (one animal unit increase per hectare) resulted in 10.6% more utilization (consumption) per hectare of the rangeland (Table 6).

On the other hand, mountain relief indirectly affects the rangeland vegetation through affecting climatic factors, e.g., orographic precipitation on windward slopes or rain shadows on leeward slopes, wind speed, net radiation, evapotranspiration, soil moisture tension and soil temperature (Lambert and Roberts, 1976), which, in turn, significantly affect the quantity of soil organic carbon, total nitrogen and enzyme activity by altering the rate of litter decomposition and the activity of soil microorganisms (Nahidan et al., 2015).

For this reason, the northeast and southeast facing slopes yielded the highest herbage as the northwest and southwest slopes yielded the lowest (Figure 3a), though the yield differences among the aspects were not meaningful ($p>0.1$).

Dry forage yield model suggested that when shifted from the reference flat (zero) aspect to the northwest slopes, rangeland dry forage yield decreases in about 600 kg per hectare. This contradicts the observation of Wangchuk et al. (2013), who reported higher dry forage yields on the north-westerly slopes. Similarly, Okatan et al. (1999) reported higher yields for the plots with a northerly aspect compared to those with a southern aspect. However, Pournemati et al. (2017) reported that there was no significant relationship between total production and topographic factors ($p>0.05$). Thus, different researchers reported different results. The reason for this discrepancy might be that southerly aspects receive more sunshine in the northern hemisphere while northerly aspects are cooler and more humid than southerly aspects in general. Therefore, southern slopes, especially in the years with sufficient rainfall, are expected to produce more herbage due to more photosynthesis. However, soil nitrogen is also another important factor limiting plant vegetative growth in a majority of ecosystems (Tisdale et al., 1995) and southern slopes are expected to have less organic matter content and so nitrogen, because of warmer temperature and more xeric nature than northern slopes (Maren et al., 2015), which may also limit plant growth despite availability of sufficient moisture in soils. Thus, according to the project for the National Rangeland Utilization and Management, the organic matter content of the southern slopes was 3.39 ±0.28% and that for northern slopes was 3.93 ±0.31% in Erzurum province (Avağ et al., 2012). Thus, as seen from Figure 3a, the southeast and northeast facing slopes showed the highest yield in both years with different rankings, the southeast facing slopes ranked first in the humid season of 2007 while the northeast facing slopes ranked first in the drought season of 2008.

Regarding the aspect and utilization rate relationship, as in line with our findings, Tamartash (2012) reported that slope and aspect are highly correlated with livestock utilization. As stated earlier, in the years of low forage production, utilization rate gets significantly higher (Table 6). However, as also clearly seen in Figure 3b, the scarcity of forage in the northwest slopes did not result in a higher utilization rate as the southwest slopes had the highest utilization rate (11%) with reference to flat as-pect ($p<0.01$) although the northwest and southwest slopes produced the lowest dry forage yield, when compared the both slopes in terms of their utilization rates. This might be explained with the preference of village herders for southwest facing slopes due to warmer temperature and their aversion to northwest facing slopes due to a cooler temperature. Nevertheless, further studies are needed to prove the present findings.

Conclusion

Rangeland forage production was negatively and significantly affected by grazing season, most likely due to negative precipitation balance in the second year. Again, significantly ($p<0.05$) increased utilization rate against very significantly ($p<0.01$) decreased forage production in the second year suggests worsening grazing pressure on rangelands in the years of low forage production. Moreover, stocking rate was determined to be an important factor causing yield losses and increasing the grazing pressure on rangelands. Thus, the rangeland sites with a heavy grazing pressure history significantly yield less forage. When it comes to rangeland condition, despite its ineffectiveness on forage yield, its positive effect on utilization rate indicates selective grazing of the animals. That is, good condition sites were grazed more heavily. Another noteworthy finding is related to altitude and geographic aspect. Despite its insignificance, high-altitude sites produce less forage ($p>0.05$) but are significantly more utilized ($p<0.05$). Similarly, east ($p<0.05$), northwest ($p<0.01$) and southwest ($p<0.1$) slopes significantly yield less forage but except northwest, east and southwest slopes were significantly ($p<0.01$) utilized more compared to reference flat (zero) aspect. Accordingly, following conclusions and lessons can be drawn from the study;

1. Because of heavy grazing pressure versus low forage production, high-altitude sites, east and southwest slopes should specifically be given the priority in rangeland restoration and rehabilitation.
2. Due to the xeric nature of southerly slopes, drought resistant species should be preferred for the over-seeding practices
3. Overgrazing also brings about or accelerate erosion in rangelands. Rehabilitation of the eroded rangelands is difficult or most of the time impossible. To avoid excessive exploitation and to realize balanced utilization in all rangeland sites, user-friendly grazing plans fitting well to the socio-cultural and socio-economic conditions of the villagers should be developed and strictly followed by each village authority.
4. Heavy grazing pressure on rangelands gets even worse in drought seasons. Therefore, this point must strictly be considered in grazing plans not to cause herbage yield losses in subsequent years.

Compliance with Ethical Standards

Conflict of interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author contribution

The author read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

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Data availability

Not applicable.

Consent for publication

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