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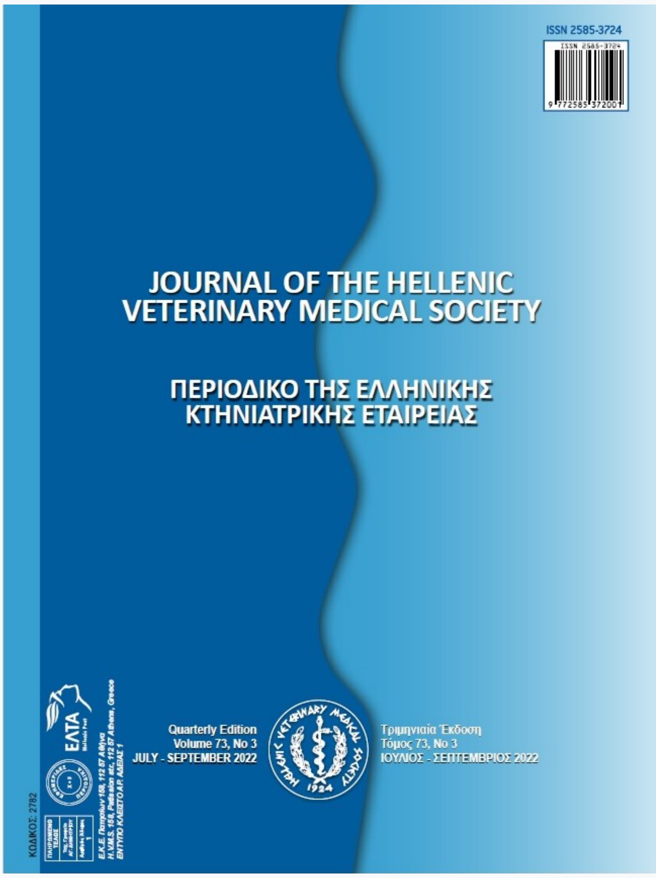

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Use of a Global Positioning System (GPS) to Manage Extensive Sheep Farming and Pasture Land

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ABSTRACT: The terrestrial climate is not sufficient to produce enough food to meet the roughage needs of the animals benefiting from the pasture lands because of excessive and early grazing of those areas. Plant growth is adversely affected in pastures that are not uniformly grazed. Tracking animals using the Global Positioning System (GPS) is a very important factor in determining the uniform distribution of grazing animals in a pasture, increasing the utilization rate of the pasture, and saving costs and time. With GPS tracking systems, establishing more effective pasture-use systems by monitoring the feeding regimes of small animals, the status of feed in the pasture, and the grazing behavior of the animals would be possible. The present study aimed to investigate the use of GPS for pasture and herd management in Turkey in addition to using the traditional techniques.

In the present study conducted in the village of Köseyusuflu in Yozgat Province in May 2017, 2018, and 2019, grazing benefits that were determined from the pasture containing two Akkaraman sheep herds were recorded using GPS tracking devices. The results suggested that the area covered with vegetation along the sheep's spring grazing routes varied between 43.6 and 62.9%, the ratio of legumes in the pasture grass in the low grazing areas was between 0.50 and 4.10%, and the grass species were between 12.75 and 44.50%. We determined that the sheep in herd A traveled between 7.6 and 9.9 km, while the sheep in herd B traveled between 4.7 and 5.7 km daily, and the two herds grazed an average of between 122 and 254 daa.

Keywords: GPS, animal tracking, pasture management, extensive sheep breeding, sheep behavior.

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INTRODUCTION

Sheep breeding plays an important role in the livestock industry and economy in terms of meat, milk, fleece, and leather products. Sheep farming, one of the oldest of all livestock-production practices, is generally conducted in settlements with pastures and generally as family businesses. There are approximately 1.21 million sheep in the world, while there are 1.05million goats (Faostad, 2017). In Turkey, the number of sheep in 2019 was 37,276,050, the number of goats was 11,205,429, and the number of small cattle was 48,481,479 (Anonymous, 2020). Sheep is one of the animals that can best assess pasture feed and can meet most of their nutrient requirements by grazing on pastures (Dağıstan et al., 2008). Because of the advantages of sheep breeding, such as their instinctively behaving as a herd; grazing long distances and on rough lands; and using crop production residues, such as stubble, and converting them into yield, this industry is a traditional and indispensable line of production, especially for farmers living in rural areas. In terms of grazing habits among livestock, because sheep graze close to the ground and lack upper incisors, the grass squeezed between their lower incisors and the upper tooth cushion allows them to grasp and assess even the shortest grasses in the pasture by moving their heads forward and upward (Çavuşoğlu and Akyürek, 2018).

Pastures provide 70% of the feed for ruminant animals worldwide (Derner et al., 2017). Although meadows and pastures comprise compositions of plants that are adapted to the region and are renewable natural resources, they can become unproductive areas within a short period if not properly managed. Irregular grazing with insufficient rainfall causes good quality forage crops in the pasture vegetation to disappear and be replaced by useless plants (Holechek et al., 2004; Babalık and Ercan, 2018). Grazing is one way to sustainably and economically benefit from pasture lands, and there should be a balance between the grass yield of the pasture lands and the number of grazing animals. "Grazing capacity" is the maximum number of animals that can graze per unit area without damaging the pasture vegetation, soil, and other elements for several years (Gökkuş et al., 1993).

Several developed countries have benefitted greatly from the practices and technology of correctly using techniques in sensitive agricultural areas and the knowledge of pasture-land capacity to keep profitability and sustainability at the highest levels. Technology is rapidly developing and the possibilities of using different technological systems in the field of animal husbandry are being researched and implemented. Classifying and mapping pasture lands using remote sensing (RS) and geographic information systems (GIS) can be done very quickly and contribute greatly to the studies in this field (Dumlu, 2010).

The use of RS and GIS technologies provides us with the opportunity to understand the spatial and temporal variability of animal, feed, soil, and pasture characteristics, the places where and times during which animals use pasture feed during grazing, and how these variables affect the use and behavior of pasture vegetation. The use of RS and GIS technologies provides a great potential to increase pasture utilization efficiency and maximize earnings by changing the herd and pasture management systems (Arnon et al., 2011; Tüfekçi, 2017). The researchers have indicated that improved global positioning system (GPS)-based animal tracking techniques are necessary to meet the rapidly developing demands in ecological research, pasture-based livestock production, and natural resource management. Unlike direct observation, GPS data allow for easy matching of a large number of spatial parameters stored in a GIS database.

In a study conducted in Israel, the researchers followed a herd of goats for 88 d by attaching a GPS device to 200 of the animals grazing in a semiarid region and analyzed the data obtained with the help of the ArcGIS program. By using this program, the researchers were able to obtain maps of the entire area in which the study was conducted, the slope of the land, the directions of the slopes, and the distance from the grazing on satellite photographs using different color scales. The researchers have stated that the animals graze on a pasture for an average of 5.5 h/d and that during this period, the herd moves at an average speed of 1.08 km/h and travels 5.4 km. (Schlecht et al., 2004; Arnon et al., 2011.)

Turner et al. (2000), in their study conducted in rural Australia, have observed the pasture and grazing behavior of cattle using GIS and GPS devices, and have reported that several environmental and governmental factors, such as pasture plant composition, plant canopy, water source, pasture soil type, pasture slope, and size of fences, affected grazing.

In another study on Nelore cattle in Brazil, Kjellqvist (2008) has observed the grazing and behaviours of 21 cattle in different pastures using a GPS tracking device attached to their necks. The researcher has determined that cattle are more active in the afternoons than in the mornings and have shorter active periods during the night.

Putfarken et al. (2008), in their study in northern Germany, have investigated free-grazing behaviours of cattle and sheep in an area encompassing 180 ha by attaching GPS to the animals. The researchers have stated that when the amount of grass is high, cattle remain in humid and productive habitats, while sheep remained in dry and nutrient-poor habitats and closer to corrals. In the study on cattle in northern Australia, Handcock (2009) has reported that the data obtained using GPS can be used by combining the satellite images obtained by remote sensing to determine the animal-pasture relationship and that this technology offers a great potential for understanding the social behavior of these animals. Trotter et al. (2010)have stated that collar-type GPS devices can determine up to 99% and with very little cost the daily activities of animals grazing in pastures within close range.

Williams et al. (2011) have reported that sheep are not very active at night but that their daytime grazing and wandering activities are intense, travelling an average of 1.99 km/d in summer; however, they emphasized that it is possible to determine grazing density and areas to be protected using just GPS.

Olsen (2014) has reported that approximately 10% of free-grazing sheep are lost every year for various reasons in unrestricted mountain/forest areas used for summer grazing in Norway. The study indicated that the GPS provides important benefits in terms of herd tracking and provides an easy-to-use sheep-tracking system that yields good results for identifying grazing areas, detecting predator attacks (e.g., when several animals start running at the same time), detecting possible deaths (e.g., immobility for a period of time), and helping to easily collect the herd at the end of the grazing season. In a study conducted in Norway, GPS collars were attached to 51 sheep from two different races of sheep on a pasture with two different yield characteristics (weak and good). The sheep were freely grazed for 60 d in 2013 and 2014, and the effect of pasture quality and race differences were measured. The researchers have reported that race differences do not affect pasture quality in terms of evaluating pasture lands.(Jorgensen et al., 2016.)

Gaur et al. (2016), in their study conducted in India to determine the migration routes of sheep herds, especially in dry seasons, have stated that tracking the flocks using GPS helps mark the migration routes and grass compositions in the pastures on the roads.

Pittarello et al. (2017) have used GPS collars on sheep in Italy to determine, according to herd density, the sheeps' consumption of specific grass species in pasture parcels that comprised different types of plants. The researchers have stated that *Bromus erectus, Koeleria vallesiana*, and *Stipa pennata* were the species the sheep ate the most of all pasture plants; however, they did not like the spiny, rosette plant species and lying grasses. Livestock management and grazing should be planned for the conservation and sustainable management of the botanical composition of the pasture lands (Pittarello et al., 2016).

GPS tracking and integrated motion-sensing technologies allow producers to remotely monitor the behavior and welfare of their livestock in large pastures (Bailey et al 2018; Ungar et al 2018). Zampaligré and Schlecht (2018), in their study on livestock feeding behavior in different land-use classes in West Africa, have reported that determining daily grazing routes using GPS tracking is very beneficial for land conservation and management. They have stated that sheep and goats most often graze near water, and emphasized the importance of preserving and improving the remaining pasture areas based on information from their land use classes.

MATERIALS AND METHODS

The present study was conducted in Köseyusuflu village Yozgat. 39 pasture parcels in the village varied between 2 and 1006 daa each (Fig. 1). The total pasture area was 6491 daa. In addition, 215 culture breed cattle, 120 crossbreeds, and 22 native breed cattle were bred in the village (Anonymous, 2020b). Dry agriculture was cultivated in the village, and there were no forage crops except Hungarian vetch. The present study was conducted in May 2017, 2018, and 2019. The average 3-year temperature was 18.5^{o}C, with the highest being 21.6^{o}C and the lowest being 9.7^{o}C. The average rainfall in May was 114.6mm (Anonymous, 2020c); rainfall in winter and spring is intense. Precipitation during the winter months is usually in the form of snow, which begins in early November and continues until the first week in May. July is the hottest month with an average temperature of 19.2^{o}C; February is the coldest month with an average temperature of -2.1^{o}C. The temperature can drop to -24^{o}C in winter (Anonymous, 2020b).

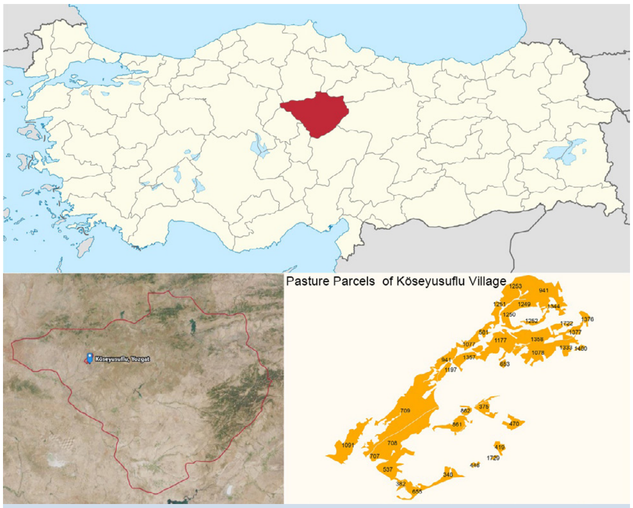

Figure 1. Map of the study area in Yozgat Province (Köseyusuflu village)

In the village used in the study, a GPS tracking device and a pedometer were attached to each sheep that was 7-12 months old to represent the herd, and pasture grazing was monitored during spring (Tüfekçi and Mülayim, 2017). The average herd population in Köseyusuflu village was 435 in herd A and 350 in herd B, and all the sheep studied were Akkaraman species.

Treyki and IMT-54 model GPS tracking devices were used, which were small and light on the necks of the sheep, according to the method ofTüfekçi and Mülayim (2017). The GPS tracking devices were adjusted and tested to send data every 10 min.Sleeves were designed in the form of a collar to prevent the devices from being affected by the field conditions, and the device was placed inside the sleeve and attached to the sheep's neck (Figs. 2 and 3).

Figure 2. Attaching the global positioning system (GPS) tracking devices to sheep

Figure 3. The global positioning system (GPS) tracker attached to the sheep

Numerical data on different qualities were obtained within the scope of the study, and cadastral information on the project site was available. Using a GIS program, maps in the form of circular color scales were obtained from the distance relationship obtained using the village settlement as the center. The information on the herd's daily distance travelled and speed was calculated by taking the data from one sheep in the herd. The daily feed requirement of the sheep was met from only the pasture during the trial.

Studies were conducted on pasture vegetation at 100 points using the modified wheel point method in the grazing pastures in May of each year, and the results of the measurements were determined by calculating the amounts of both the vegetation-covered and bare areas Koç and Çakal, 2004; Yavuz et al., 2012; İspirli et al., 2016). The degree and location information was obtained after omitting the resting periods (e.g., corrals, gardens, and paths) of the herds tracked in the study and were transferred to the GIS program and, as stated in Tüfekçi (2017), an affine transformation was mapped to be compatible with the litter.

The data obtained in the field studies were analyzedusing ArcGIS. Digital orthophotos were used as a map base in the GIS program. Parts of the orthophotos belonging to the project area were used as raster.

In the present study, the relationship between GPS tracking recordings and vegetation was determined according to the survey results, and a comparison of these data with satellite photos was made; therefore, the number and frequency of the surveys were kept to the minimum required. In addition, the regions and areas where the herds traveled most and least were determined from the data obtained from the animal movements during the study period and matched with the satellite photographs. All surveys conducted were tagged with a GPS receiver in numerical coordinates.

RESULTS

The results of the surveys of the present study were divided into the pasture and non-pasture areas (e.g., fallow, stubble, field, and non registration). The results from the spring pasture vegetation study are provided in Table 1. As a result of the pasture study conducted using the modified wheel point method, we determined that the vegetated areas varied between 43.6 and 62.9%. In particular, as the altitude increased, the vegetated area, and subsequently, the yield and quality of the pasture, decreased.

The results of the measurements using the modified wheel point method are provided in Table 1, which-shows the percentages of vegetated and bare areas. Based on the type of plant groups forming the vegetation, the vegetation study percentages are provided in Table 2. The species in the mixture comprised *Astragalus* sp*, Acanthus hirsutus, Achillea schischkini, Aegilops* spp. *Aegilop striuncialis, Agropyron repens, Anthemis cotula, Arthemisia absinthium, Avenafatua, Bromus arvensis, B. erectus, B. tectorum, B. tomentellus, Centaurea cyanus, C. iberica, Circium arvense, Ci. rhizosephalum, Elymus* spp. *Erodium cicutarium, Eryngium campastre, Euphorbia characias, E. orientalis, Festuca ovina, Hedys arumvarium,Hordeum murinum, Hordeum* spp.*, Hypericum perforatum, Lactuca serriola, Lotus cornicularis, Medicago lupulina, M. polymorpha, Medicago spp., Ranunculus asiaticus L., Salvia cryptantha, Scorzone acana, Sinapis arvensis L., Thymus leucostomus, and Vebascum thapsus*. According to the vegetation studies, the ratio of legumes in the pasture was very low and the rate of benefited grasses was low, so the pasture was poor.

The average distance covered by the herds on the pasture in the spring months varied between 4.7 and 9.9 km. The distance travelled and grazing area of herd A was longer because the pastures were farther apart. Because the village in which the study was conducted had a water source in only the area in which herd A was grazed (in the last pasture plot), this herd rested there and returned to the corral from this parcel. Herd B returned to the corral to rest at the end of the grazing period because there was no shade on the pasture. The distance that the sheep covered during grazing varied depending on the genetic differences in the races and the water and feed conditions surrounding the herd (Squires, 1975; Broom and Fraser, 2007). It has been reported that the total distance travelled by grazing sheep varies between 8 and 16 km/d, with a large variation in reported distances (Cresswell, 1960; Fraser, 1974). Daily walking distances have been reported as 14 km for Border Leicesters, 13.7 km for Merinos, and 9 km for Dorset Horns (Squires et al., 1972). Walking speeds are 2.2-2.7 km/h for Border Leicesters and Merinos but only 0.8 km/h for Dorset Horns. The availability of water is a factor that determines grazing behavior, especially in arid regions. When the environmental temperature decreases, water consumption also decreases, and when water is limited, feed consumption decreases (Arslan, 2007).

Table 1. The 3-year spring vegetation survey of the average size of vegetation-covered and bare areas

Study	Altitude (m)	Date of Study	Number of Points	Area Covered with Plants (%)	Bare Area (%)
1	1.210	May 15 2017	400	62.9	37.1
2	1.210	May 21 2018	400	55.0	45.0
3	1.210	May 10 2019	400	43.6	56.4

Table 2. Percentages of vegetative and bare areas according to plant groups in the studied areas

Sample sites	Grasses	Legumes	Other	Bare area	Total vegetated area
Field 1 - Low grazing (parcels 941, 1253, 1249)	44.50	3.54	31.00	20.96	79.04
Field 2 - Intensive grazing (parcels 1077, 941, 1197, 1357)	18.35	0.50	29.50	51.65	48.35
Field 3 - Intensive grazing (parcels 707, 708, 537)	12.75	1.16	26.75	59.34	40.66
Field 4 - Low grazing (parcels 1358,1177)	31.25	4.10	24.5	40.15	59.85
Field 5 - Low grazing (parcels 709, 348, 655)	26.50	3.25	34.00	35.55	64.45
Mean	26.67	2.51	29.15	43.53	58.47

The sheep walk 0.6 km/h during grazing and 4 km/hto reach the water source(Squires, 1974).

Table 2 and Fig. 4 show that overgrazing areas and the plant species, and indicate that that the amount of legume species was very low.

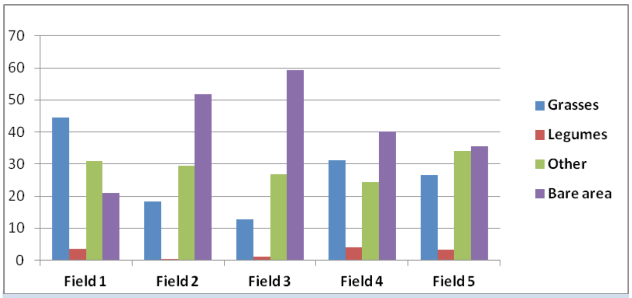

Figure 4. Distribution (%) of spring vegetation in the study area

Examining the vegetation percentages in the areas with low grazing, we observed that the majority of the plants were not eaten by animals. These areas were not grazed because the plants were not tasty and those that were bushes were harmful to the animals. The legume and grass fodder crops have decreased from consumption, and the plants belonging to other families decreased from chewing. Because of grazing and chewing activities, there is the less vegetation-covered area in the parcels that are closest to the corrals. Bare areas are those without vegetation and covered with soil and stones.

Among the studied herds, herd A uses plots 941, 1253, and 1344 that is9.9 kmfrom the pasture area. The herd begins to move from the corral toward the pasture area at ~5:30-6:00 a.m., grazes an average of 4-4.5 h, and then reaches the wetland. We observed that the herd fulfil sits need for drinking water using the basin within this region and then rests and ruminates under the trees. The herd returns from the same route to the corral in the afternoon; this usually takes 4-4.5 h. Herd B, on the other hand, graze mostly in the plots close to the pasture (plots 537, 707, and 708), return to their pen at noon, and spend their active rest (rumination) lying in the open paddocks of the pen; they go to the pasture again in the afternoon.

In the present study, the herds were not fed additional food in May for the 3 study years, and the sheep used in the study were not part of the main herd and were grazed on separate and closed pastures. Figure 5 shows the grazing routes of herds A and B that were mapped in May 2017, 2018, and 2019.

In the study conducted on Akkaraman sheep, the stepping distance of the sheep was calculated to be within the range of 28-30 cm and the sheep took ~33,000 steps getting the farthest distance (9.9 km) away. The average daily grazing areas and grazing

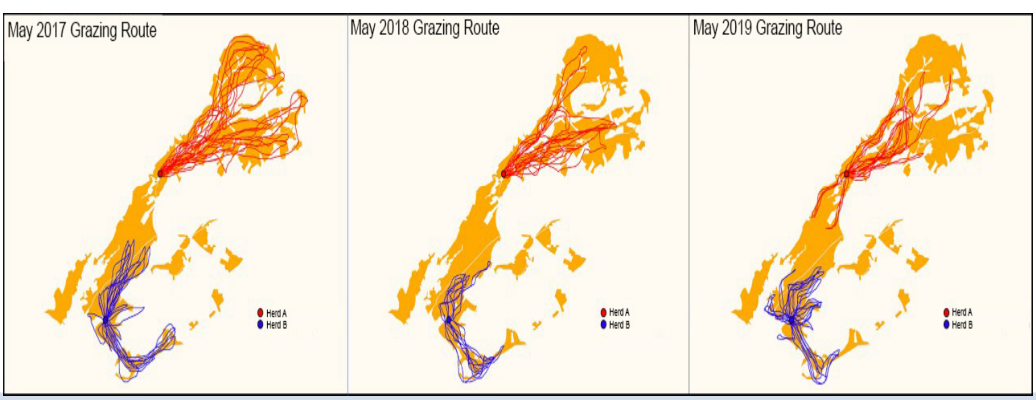

Figure 5. Grazing routes of herds A and B in May 2017, 2018, and 2019

Table 3. Average daily grazing areas and grazing distances of herds A and B in May of each year

Year	Herd	Average daily grazing distances (km)	Average daily grazing land size (ha)	Measured grazing area/ km (ha)	Reference grazing area/ km (ha)	Difference (ha)	Repetitive grazing (%)
2017	A	9.9	25.4	2.6	12	9.4	78.62
	B	5.4	17.5	3.2	9	5.8	63.99
2018	A	7.6	23.2	3.1	12	8.9	74.56
	B	5.7	14.5	2.5	9	6.5	71.73
2019	A	8.2	24.7	3.0	12	9.0	74.90
	B	4.7	12.2	2.6	9	6.4	71.16

distances of herds A and B are presented in Table 3.

Table 3 shows that the average daily trip distance of herd A in May 2017 was 9.9 km.A grazing area 120m wide is equivalent to one 9.9 km x 120m or 1188 daa, while the area measured on the map was 254 daa. This difference of 934 daa was the result of repetitive grazing. From this, we calculated repetitive grazing as 934/1188 x100 = 78.62%. The fact that the pasture was weak and the herds used the same range of pasture routes indicated repetitive grazing. The repetitive grazing by herd Aconstituted78.62% in May 2017, which made it the largest area grazed over the 3 years.

The daily trip distance of herd A ranged between 7.6 and 9.9 km; that for herb B ranged from 4.7 to 5.7 km; however, the rate of repetitive grazing was high for both herds, ranging from 63.99 to 78.62%. It can be argued that the biggest reason for this high rate was the size of the herd, grazing on the same pasture, and the use of the same pastures as the round-trip routes. Although there were 39 pasture parcels in the village in which the study was conducted, we observed that the shepherds used the same pasture parcels and routesbecause some parcels were very small, some were located over mountainous lands, and some were between fields. The overgrazing in April, May, and June of these pasture parcels, which were close to the sheep corrals and were relatively flat and highly productive, weakened the pastures. In addition, we observed that sheep herds grazed on the stubble fields and the pastures adjacent to these fields during the summer months.

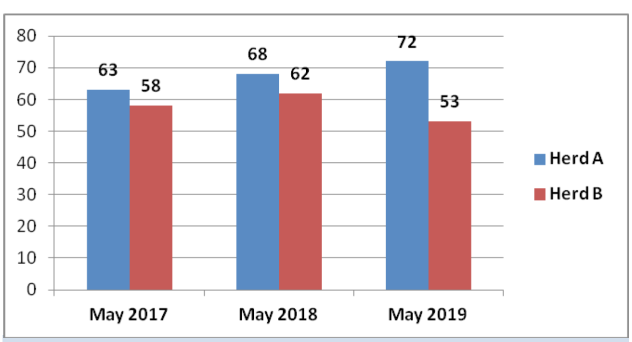

Figure 6. Grazing rates of herds A and B in May 2017, 2018, and 2019

Figure 6 shows that the grazing ratios of herd A were 63, 68, and 72% in May 2017, 2018, and 2019, respectively, while those of herd B were 58, 62, and 53%, respectively, in the pasture areas. In their study on two herds in Konya, Tüfekçi and Mülayim (2017) assessed the grazing areas inside and outside of the pasture from June through October. The researchers found that grazing ratios in the pasture for the first herdwere 44, 22, 42, 28, and 17%, respectively, within the relevant months, while those of the second herd were 60, 27, 15, 27, and 37%, respectively, during the same months. These results were similar to those obtained in the present study.

CONCLUSIONS

Tracking animals using GPS is of great importance for producers in terms of reducing both costs and time. Using GPS technology makes it possible to determine suitable grazing routes of small cattle herds grazing in the pastures and for shepherds to graze their pasture areas by pasture management using these routes. Producers would have the opportunity to instantly track the status of the herds they entrust to their shepherds, herd mobility, herd routes, and the distances the herds travel.

Creating and implementing grazing plans for the pasture lands using GPS technology will help to resolve the problems of needing to find qualified shepherds and avoiding poor pastures, which are the biggest problems in the cattle-breeding industry, and the producers would be able to follow their grazing animals on their mobile phones or computers; however, there is a need for more studies on this technology, the development of new cameras and animal-tracking systems, and how to increase the life of the tracking batteries. It was suggested that the work of subject experts would increase the uses in this sector.

Considering the results obtained, and especially those on repetitive grazing, we observed that geometrically thin and long parcels were exposed to more repetitive grazing than those that were nearly square. In particular, in the pastures with the same leaving and returning routes, we observed that the parcels closest to the corral or village were subjected to excessive grazing and chewing; therefore, particularly during cadastral and land consolidation studies, it has been predicted that the pasture parcel nearly square and those distributed around the corral or the village, rather than along a thin line,would provide more evenly balanced grazing.

Daily grazing routes can be determined according to herd size using GPS tracking devices to monitor the movement of the animals in the pasture, and a pasture-management plan can ensure that the animals graze by the planned management technique, which wouldprotect the vegetation structure in the pasture areas by preventing excessive grazing.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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