engineering proceedings

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Proceedings Paper

Using GPS Tracking Collars and Sensors to Monitor the Grazing Activity of Browsing Goats in Forest Rangeland †

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† Presented at 9th International Electronic Conference on Sensors and Applications, 1–15 Nov 2022; Available online: https://ecsa-9.sciforum.net/.

Abstract: The recent advancements in sensor technologies to monitor and record behavioral activities of livestock provide an accurate scope to extend the database and understand the animal behavior under actual grazing conditions. The aim of this work was to determine the seasonal variation in grazing activities of goats using the Global Positioning System (GPS) and leg sensor technologies. The study was conducted in the Southern Mediterranean forest pasture of Northern Morocco. Eight dairy alpine goats have been fitted with GPS tracking collars and tri-axial accelerometers over a 3-day period of each grazing season (spring, summer, and fall). Most of the behavioral activity of goats was dedicated to grazing (36 to 59%), followed by resting (22 to 30%) and walking without grazing (10 to 24%). During summer and fall, goats traveled longer distances compared to the spring. The combination of the two studied sensors provided useful data information to understand the behavioral activity of goat grazing in forest pasture.

Keywords: GPS collars; accelerometer; behavioral activity

Citation: Chebli, Y.; Otmani, S.E.; Cabaraux, J.-F.; Keli, A.; Chentouf, M. Using GPS Tracking Collars and Sensors to Monitor the Grazing Activity of Browsing Goats in Forest Rangeland. **2022**, *4*, x. https://doi.org/10.3390/xxxxx

Academic Editor: Francisco Falcone

Published: 1 November 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

In Northern Morocco, forest rangelands largely contribute to the livestock feeding, mainly of goats [1]. These forest pastures constitute an important fodder reserve, guaranteeing a permanent forage source for goats during feed gaps and drought periods [2]. Animal grazing is associated with very different daily activities than sedentary animals, such as movement and walking distance [3,4]. Unfortunately, few studies have focused on the grazing activities of goats, especially in woodlands. For aiding the spatiotemporal management of goats on forest rangeland, it would be critical to discover the relationship of goats to their environment to develop targeted decisions to optimize animal performances and sustainable management of livestock [5].

Advances in the development and use of the global positioning system (GPS) and accelerometer technology have brought useful near-real-time information on animal activity and behavior to increase livestock productivity and monitor the animal space use [6]. In this context, this study aimed to evaluate the potential of smart grazing by using GPS collars and leg sensors as a tool for the monitoring of the grazing activities of goats in the Southern Mediterranean forest rangeland of Northern Morocco.

2. Materials and Methods

2.1. Study Area

The present study was carried out in the Northern side of Morocco which is a part of the Mediterranean region. The study area is situated in the mountainous forest rangeland. This region is characterized by a humid and sub-humid climate, with dry summers and wet winters. The mean monthly precipitation lies between 200- and 800-mm during winter months. The mean monthly temperature also shows seasonality and varies between 3 to 14 °C in winter and from 18 to 38 °C in summer. The species composition of the studied forest rangeland includes oak cork (*Quercus suber* L.), strawberry tree (*Arbutus unedo* L.), *Cistus* species ((inclusive of *C. crispus, C. monspeliensis,* and *C. salviifolius*), topped lavender (*Lavandula stoechas* L.) common myrtle (*Myrtus communis* L.), and broad-leaved phillyrea (*Phillyrea media* L.).

2.2. Data Source

The present experiment was carried out with livestock herd from Derdara village (35°08′ N; 5°18′ W). The goat farm was chosen among the most representative in the region. Grazing activity measurements of goats were collected during the three days of the main grazing seasons (spring, summer, and fall). The winter has been excluded from the study because the goat herds are confined in the shed.

Eight dairy goats of alpine breed were equipped with GPS collars (3300SL, Lotek Wireless, Newmarket, ON, Canada) on the neck and tri-axial accelerometers (IceTag, IceRobotics Ltd., Scotland, UK) positioned on the rear left leg (Figure 1). The GPS collar was used to estimate the locomotion activities (traveled distance, speed, and altitudinal locomotion). The leg sensor was used to estimate the lying and standing activities, and step number.

ArcGIS 10.x (ESRI, Redlands, CA, USA) thought data management tools was used to calculate in meters the coordinate system (x, y) for each fixed record from GPS collars. The Euclidean geometry between two successive couples of fixed locations L1 (x1, y1) and L2 (x2, y2) was used to calculate the horizontal distance (HD).

$$\mathrm{HD} = \sqrt{(\mathrm{x}_2 - \mathrm{x}_1)^2 + (\mathrm{y}_2 - \mathrm{y}_1)^2} \quad (1)$$

The difference between two consecutive altitudinal positions (z1) and (z2) was used to calculate the vertical distance (VD).

$$\mathrm{VD} = \mathrm{z}_2 - \mathrm{z}_1 \quad (2)$$

The total traveled distance (TD) by each experimental goat was calculated as:

$$\mathrm{TD} = \sqrt{(\mathrm{HD})^2 + (\mathrm{VD})^2} \quad (3)$$

A trial (calibration) was conducted to monitor the grazing activity of eight goats fitted with GPS collars and leg sensors in the studied forest rangeland. The calibration was performed before the experimentation over a 3-day period using direct visual observations of animal behavior. Data from calibration was used to predict the grazing activities of each experimental goat using the classification and regression tree analysis of the collected data from electronic monitoring sensors [7,8].

Figure 1. Alpine goat equipped with a GPS collar on the neck (red) and leg sensor positioned on the rear left leg (yellow) in the studied forest rangeland of Northern Morocco.

2.3. Data Analyses

Statistical data analyses were performed using SAS software (SAS version 9.x, New York, NY, USA). Grazing activity data were evaluated according to the PROC MIXED procedure with the daily observation on each goat as experimental unit. The behavioral variables were compared across seasons (i.e., spring, summer, and fall). To reveal significant differences between tested effects, all the analyses were followed by Tukey's HSD post hoc test, adopting a significance level of $p \leq 0.05$.

3. Results and Discussion

All behavioral variables recorded significant differences within each measurement season ($p < 0.01$) (Figures 2 and 3).

Figure 2 displays the seasonal importance of grazing activities of browsing experimental goats in the studied forest rangeland. According to the classification and regression tree analysis, the percentage of time spent grazing (eating) was more important in spring (59%) compared to summer (36%) and fall (45%). As reported by several authors [2,9], the high forage availability recorded during spring explains the increased time allocated for grazing. Conversely, the low forage availability recorded during summer and fall could explain the longer time reserved for walking without grazing. During these two seasons, the preferred and more selected plants species by goats are scarce which explain longer time spent for searching of palatable vegetation. The walking activity is more related to the longer duration of forage search and selection by animals [10]. The proportions of time spent grazing and lying were higher in summer (15%), followed by fall (9%) and spring (5%). In the studied forest rangeland, lying activity was more concentrated at mid-day when the sun is highest. During summer, goats prefer to huddle together under the shadows of the trees to avoid the mid-day heat. Resting while standing was slightly higher during summer (30%) and similar during spring and fall (about 25%). Similarly, several authors stated that the grazing animals are more energetic during the first and the end hours of the days but less active during the mid-day due to the heat and the humidity [11,12].

Figure 3 shows the seasonal variation of locomotion activity of browsing experimental goat. The locomotion activities daytime budgets were different among seasons ($p < 0.001$). According to the GPS collar data, the horizontal and vertical distances traveled by the experimental goats were significantly higher and similar during summer and fall

($p < 0.001$). Similarly, the number of steps was recorded the greater values during the summer and fall (>6500 steps) compared to the spring (5200 steps). As reported par Charnov [13], the low forage availability causes an increase of time spent by animals to the search of the palatable vegetation which, consequently, increases their locomotion activities such as the number of steps.

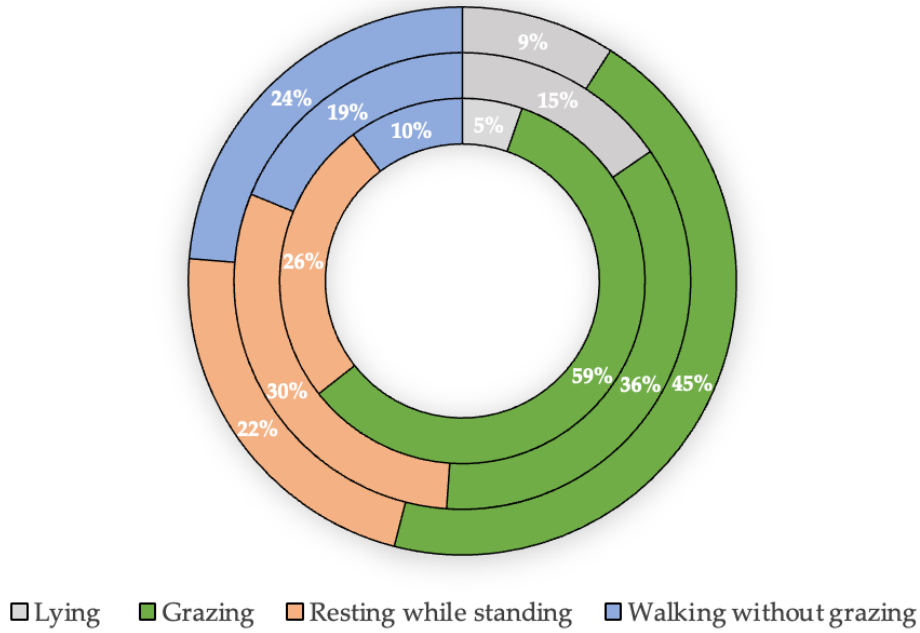

Figure 2. Seasonal importance of grazing activities of browsing experimental goats in the studied forest rangeland of Northern Morocco. From the inside to the outside in order of spring, summer, and fall.

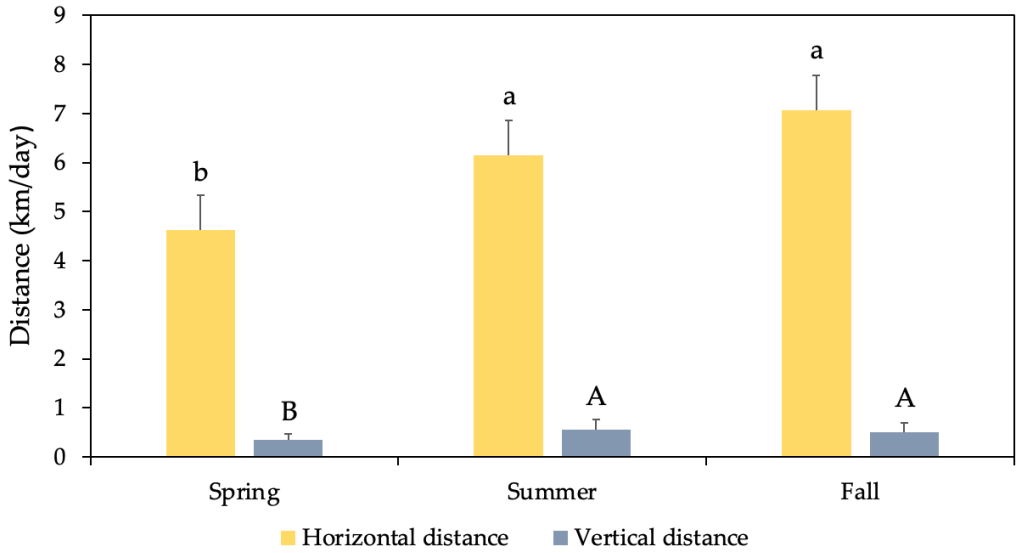

Figure 3. Seasonal variation of *locomotion* activity of browsing experimental goat in the studied forest rangeland of Northern Morocco. [a–b] horizontal, or [A–B] vertical distances values with different letters are significantly different ($p < 0.05$).

3. Conclusions

It could be concluded that the grazing activities of goats are mainly dependent on the season. The combination of GPS collar and leg sensor technologies to monitor and record the grazing activities of goats provide useful data information to understand the grazing behavior of animal browsing in complex Southern Mediterranean forest rangelands.

Author Contributions: Conceptualization, Y.C.; methodology, Y.C., S.E.O., K.A. and M.C.; formal analysis, Y.C. and S.E.O.; investigation, Y.C. and S.E.O.; data curation, Y.C., S.E.O. and M.C.; writing—original draft preparation, Y.C., S.E.O., J.F.C., A.K. and M.C.; project administration, Y.C., J.F.C. and M.C.; funding acquisition, Y.C. All authors have read and agreed to the published version of the proceedings paper.

Funding: The research leading to these results was funded through the National Institute of Agricultural Research (INRA, Morocco) and the Academy for Research and Higher Education—Development Cooperation Committee (ARES-CCD), Brussels (Belgium).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to extend our gratitude to the goat herder of Derdara (Chefchaouen province) for their help and participation in this study.

Conflicts of Interest: The authors declare no conflict of interest.

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