Application of precision livestock farming to monitor the grazing behavior of goats*

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Abstract

The advancement of remote monitoring technologies, such as global positioning systems (GPS) and three-axis accelerometers, offers valuable opportunities for gaining insights into the behavior of grazing animals by capturing data at various spatial and temporal scales. This study aimed to classify different behavioral patterns in grazing goats through the integration of GPS collars, accelerometers, and satellite remote sensing. The research was conducted in the mountainous forest rangeland of Beni Arouss, Northern Morocco, using goats from an extensive local farm. Goats were equipped with GPS collars and leg sensors to track their grazing behaviors across seasons. A calibration process combined with classification tree analysis was employed to predict these behaviors. The results indicated that goats allocated the majority of their time to foraging in spring and autumn, while they increased their resting time during summer ($p<0.001$) at the expense of grazing. The number of steps was numerically consistent and significantly higher in both summer and autumn ($p<0.001$). Goats spent 48% of their feeding time grazing in the spring, compared to 27% in the summer and 31% in the autumn. Analysis of GPS data revealed a significant seasonal impact on the parameters measured ($p<0.001$). Utilizing GPS collars and sensors to monitor grazing behavior offers reliable data that can inform grazing management strategies and improve livestock performance.

Keywords

Sensor, GPS collar, accelerometer, behavior, grazing, goat

1. Introduction

In Northern Morocco, forest rangelands provide a valuable source of free forage for grazing livestock, particularly goats. These forest areas serve as a year-round source of feed, allowing goats to graze freely throughout the seasons [1]. Grazing in mountainous terrains also leads to increased physical activity due to the vertical movements required for navigation. This added physical exertion demands more time and energy for the animals to cover a given distance [2]. Observing and accurately measuring these activities solely through direct observation is challenging, as it is difficult to capture individual animal movements and behaviors with precision. Understanding such behavioral patterns is crucial for assessing feeding habits and interactions with the environment, which in turn informs management decisions.

Advances in Global Positioning Systems (GPS) and the growing use of accelerometers to monitor and record animal behavior offer new possibilities for collecting detailed data on grazing activities. While previous studies have mainly focused on the use of GPS and sensor technology for tracking cattle and sheep, this research seeks to apply these tools to extensive goat farming systems [3-7]. The objective is to use GPS collars, sensors, and remote sensing technologies to gain insights into

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the grazing behavior of goats, enabling better management and more efficient grazing strategies for sustainable livestock production.

2. Materials and methods

This study was conducted in the forest rangelands of Beni Arouss, located in Northern Morocco. Eight local meat goats of the Beni Arouss breed, with an average live weight of 30 ± 2.6 kg and an age of 36 ± 6 months, were selected for a three-day experiment, with eight goats tested each day. The study was carried out over three grazing seasons: spring, summer, and autumn. The goats spent most of each day grazing in the forest pastures, returning to a semi-open shelter on the farm at the end of the day. During winter, when access to the forest rangelands is restricted due to kidding season, herders cut branches from evergreen trees to provide fodder for the goats at the barn [1].

Each goat was equipped with a GPS collar and an IceTag sensor on its left hind leg for three consecutive days during each season (Figure 1). To familiarize the goats with the equipment, they were fitted with the devices several days prior to the actual data collection. The GPS data captured location, speed, and both horizontal and vertical distances traveled, which were processed using GPS3000 Host software. The collected coordinates were converted from UTM WGS84 to Moroccan Transverse Mercator format using ArcGIS 10.X. For each fixed GPS record, the horizontal coordinates (x and y) were calculated using ArcMap, and the vertical distance (VD) was determined by calculating the altitude difference between consecutive positions.

IceTag sensor data was analyzed using IceManager software, providing information on the goats' lying (resting or ruminating), standing (without eating or ruminating), the number of steps, and a movement index, which measures overall leg activity in three dimensions.

Data analysis was performed using SAS software. Grazing activity data were analyzed using the PROCMIXED procedure in SAS, comparing parameters across seasons (spring, summer, and autumn). Statistical significance was set at $p < 0.05$, and when significant differences were found, means were compared using the Tukey test.

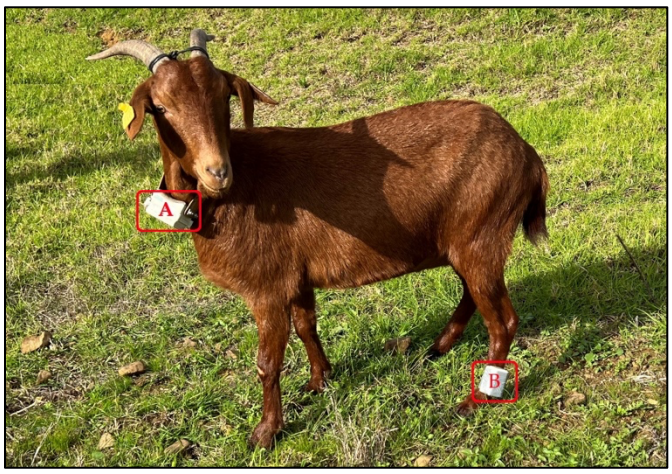

Figure 1: Experimental local goat fitted with GPS collar (A) and leg sensor (B).

3. Results and Discussion

Figure 2 (a and b) illustrates the seasonal variation in the grazing activities of goats. During spring and autumn, goats devoted most of their time to searching for palatable plant species. However, in summer, goats significantly extended their resting periods ($p < 0.001$) at the expense of grazing time. The number of steps taken was also consistently higher in both summer and autumn seasons ($p < 0.001$).

Analysis of GPS collar data revealed a significant seasonal effect on the measured variables ($p < 0.001$). During the summer, forage availability became scarce, forcing the herders to relocate their herds to different forest pastures within the region (Figure 3).

Goats covered a greater horizontal distance in both autumn and summer, with this trend also observed for vertical distance traveled. Conversely, their speed was significantly higher in spring compared to other seasons ($p < 0.001$). The length of the foraging day (the time spent grazing) was extended during the summer compared to both autumn and spring ($p < 0.001$).

According to the Classification and Regression Tree (CART) analysis, grazing time was longest in spring and comparable between summer and autumn ($p < 0.001$). Standing rest time showed no significant differences across seasons ($p = 0.191$). Walking without grazing was more common in the order of autumn > summer > spring.

These findings align with other studies on the seasonal grazing behavior of goats in similar forest pastures [2]. For example, in Tanzania's semi-arid zone, Safari et al. [8] reported that goats increased their grazing time (57–68%) and reduced their resting time (6.8–1.4%) between rainy and late summer periods, while walking time remained consistent (27%). Similarly, in Zimbabwe, goats spent the majority of their time grazing during the rainy season (52–75%) compared to the summer months (29–50%) [9].

In agreement with the current study, previous research found that goats spent 48% of their feeding time grazing during the green season, compared to 27% in summer and 31% in autumn [2]. This behavior can be attributed to the abundance of preferred shrub species (such as *Cistus spp.* and *Lavandula stoechas*) and herbaceous plants during spring. In Tanzania, Safari et al. [8] also noted that goats extended their grazing day during the summer compared to the rainy season to meet their intake needs.

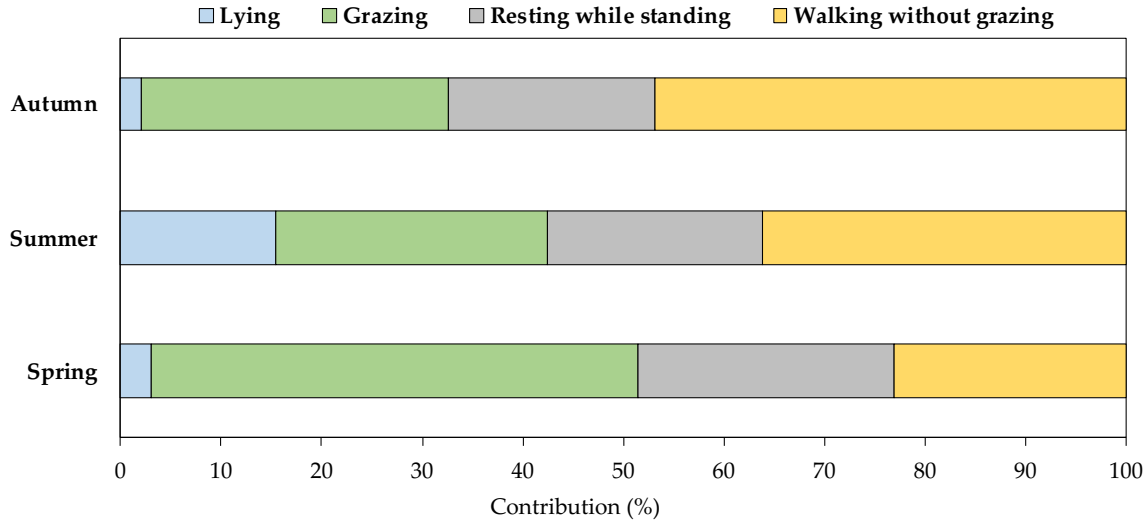

Figure 2a: Seasonal variation in grazing activities of experimental local goats browsing in Beni Arouss pasture (Northern Morocco).

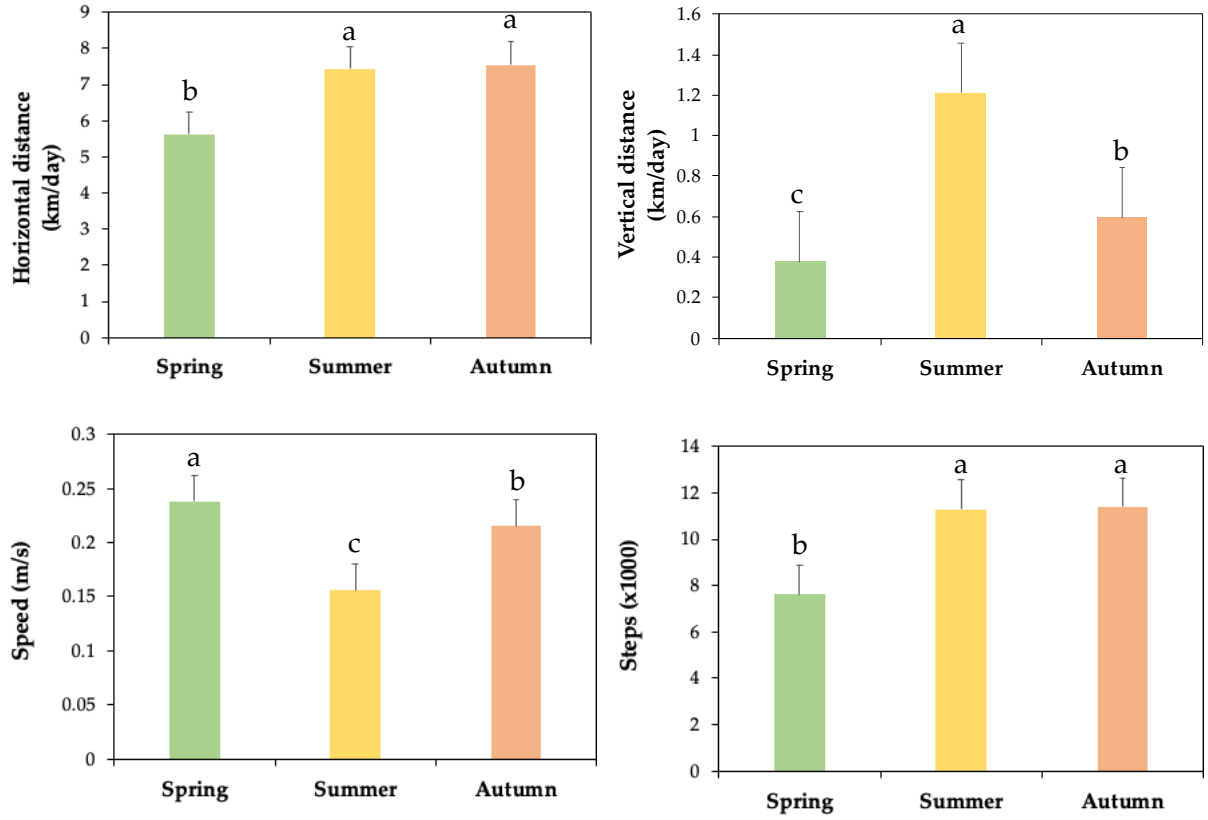

Figure 2b: Seasonal variation in grazing activities of experimental local goats browsing in Beni Arouss pasture (Northern Morocco).

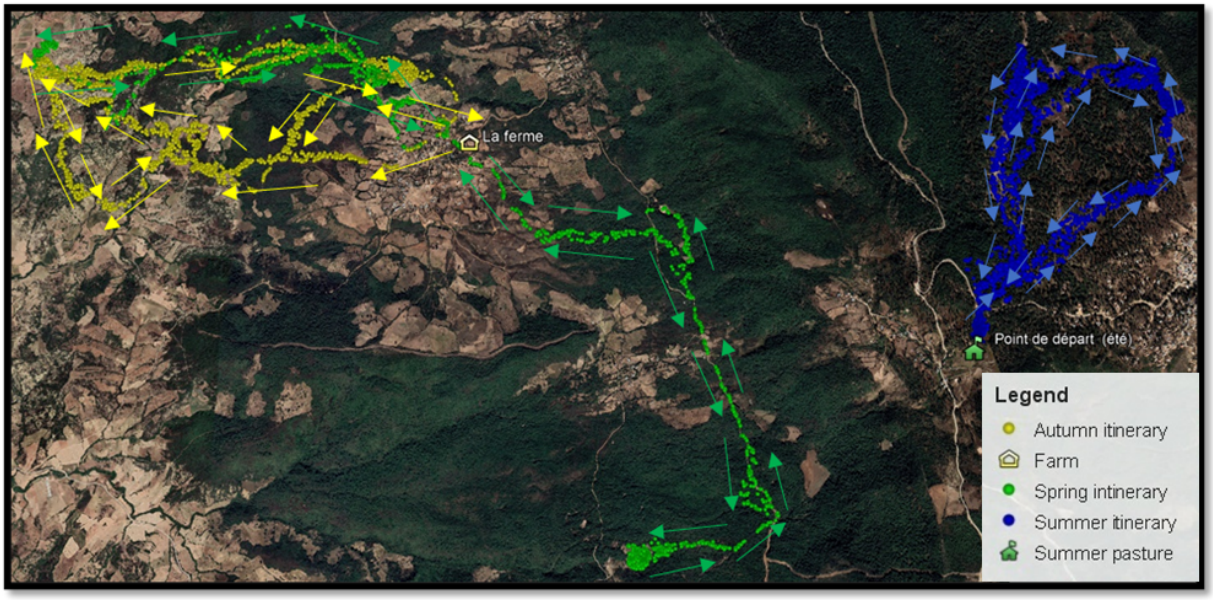

Figure 3: Seasonal variation in the displacement itineraries of experimental local goats browsing in Beni Arouss pasture (Northern Morocco).

4. Conclusions

The integration of GPS collars, accelerometers, and remote sensing technologies to track and record goat grazing activities has proven effective in providing valuable insights into their behavior within the complex forest rangelands of Northern Morocco. Understanding individual animal

movements and activity patterns is crucial for effective pasture management. Expanding this research to include other livestock systems and species could offer broader guidance on optimizing the use of forest rangelands in Morocco.

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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