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# Challenges and innovations for grasslands resilience

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# Grazing area and goat mobility in a Mediterranean forest rangeland using precision livestock tools

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## Abstract

Understanding how grazing animals interact with forest–grassland mosaics is critical for the long-term sustainability of Mediterranean rangelands. We investigated seasonal changes in goat grazing patterns and space use within a forest pasture in northern Morocco by combining GPS collar tracking with leg sensors. Monitoring was carried out in spring, summer and autumn, and GPS data were complemented with forage availability measurements to map seasonal grazing ranges. The goats travelled from 8.3 ha in spring to more than 17 ha in summer and autumn, indicating greater mobility when feed resources were scarce. In spring, goats devoted most of the daytime to grazing (48%), whereas in summer and autumn, grazing time dropped, and daily walking distances increased. Energy balance assessments showed surpluses in spring but deficits in the two other seasons, linked to longer movement times and lower forage intake. The study demonstrates the value of precision monitoring tools for capturing fine-scale animal–landscape interactions and for guiding adaptive grazing management.

**Keywords:** forest rangeland, GPS collar, grazing behaviour, Mediterranean ecosystem, sensor

## Introduction

In northern Morocco, forest pasture ensures free forage production for grazing animals. In this region, the livestock farming system is concerned with grazing goats in forest rangelands, ensuring free animal feed all year round (Chebli *et al.*, 2018). Browsing in mountainous forest rangelands of northern Morocco involves additional physical activities for the goats, such as the vertical movement (Chebli *et al.*, 2022) due to the harsh landscape characterized by steep and uneven slopes. These altitudinal movements increase the time and energy required to travel a given distance, which negatively affects livestock productivity and implicitly the household income. This kind of information is difficult to obtain only by using direct observation because observers cannot precisely measure individual animal behaviour, such as movement and activity (Hlimi *et al.*, 2024). Data on animal activities are essential to understand the feeding and grazing behaviour of animals and to identify optimal management strategies. This study aimed to: (i) assess seasonal variations in grazing area; (ii) examine changes in goat mobility and activity patterns; and (iii) evaluate seasonal energy balance using GPS collars and sensors.

## Materials and methods

The study was conducted in the forest rangelands of Beni Arouss, in northern Morocco, an area with a typically Mediterranean climate. The vegetation is dominated by holm oak (*Quercus rotundifolia*) and strawberry tree (*Arbutus unedo*), accompanied by shrub species such as *Cistus* spp. and *Erica arborea*. Eight adult, non-pregnant local goats ( $30 \pm 2.6$  kg and an age of  $36 \pm 6$  months) were fitted with GPS collars (recording positions at regular intervals) and tri-axial accelerometer leg sensors to monitor activity (Figure 1). Tracking was performed over three seasons: spring, summer, and autumn. GPS data recorded grazing periods during daylight, which were used to map grazing areas and calculate daily



Figure 1. Goat wearing a GPS collar (A) and a leg sensor (B). Downloading GPS (C) and leg sensor (D) data.

walking distances. Activity sensors classified behavior into grazing, walking, or resting. Grazing areas were estimated using kernel density methods to delineate seasonal home ranges. Energy expenditure was calculated from walking distance and activity data. Metabolizable energy intake was estimated from forage availability and diet composition to determine seasonal energy balance. The methods are described in detail by Chebli *et al.* (2022).

## Results and discussion

The spatial extent of grazing varied considerably between seasons (Figure 2). Although Figure 2 may give the impression that travel distances are higher in spring, the data clearly show that goats travelled longer daily distances during summer and autumn compared to spring. During spring, forage is abundant and spatially continuous, allowing goats to satisfy their dietary needs within more restricted areas and therefore travel shorter total distances despite high grazing activity. In spring, goats concentrated their activity within a relatively compact grazing area of 8.3 ha. This reflects a lower need to travel in search of feed, as high-quality forage was readily available near resting sites. By contrast, during summer and autumn, the decline in biomass and forage quality forced animals to expand their range considerably, exceeding 17 ha in both seasons. GPS tracking showed that grazing routes became more dispersed, with goats visiting a wider array of vegetation patches. Daily walking distances increased markedly in these periods, indicating a behavioural adjustment to reduced resource availability. This expansion of the grazing footprint during feed scarcity is consistent with patterns reported in other Mediterranean rangelands and has implications for vegetation pressure and regeneration capacity (Rodrigues *et al.*, 2013).

The goats spent 48% of their feeding time browsing (eating) during the spring, in contrast to the summer (27%) and autumn (31%). In summer and autumn, grazing time declined significantly, while the proportion of time spent walking increased. This shift suggests that animals devoted more effort to searching for dispersed and lower-quality feed resources. Periods of prolonged locomotion, combined with reduced intake, contributed to negative energy balances in these seasons (Papachristou, 1997).

The energy balance of the studied goats was positive in spring, but deficits emerged in summer and autumn due to the combined effects of lower intake and higher locomotion costs. These findings echo

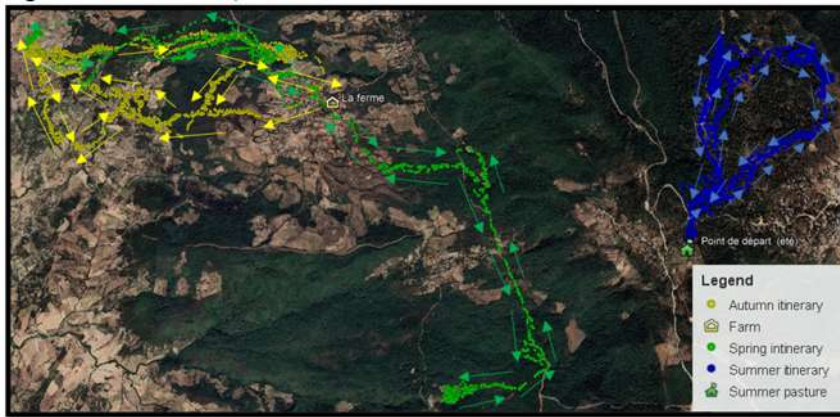


Figure 2. Seasonal movement patterns of local goats in Beni Arouss forest rangelands (Northern Morocco).

results from other Mediterranean rangelands where seasonal forage gaps compromise animal nutrition (Chebli *et al.*, 2020).

The integration of GPS tracking and activity monitoring provided a fine-scale picture of goat–landscape interactions across seasons. The observed expansion of grazing areas during feed scarcity underscores the need for adaptive stocking rates and targeted feed supplementation during critical periods. Without such measures, prolonged high mobility and energy deficits could lead to declining animal performance and accelerated vegetation degradation (Schlecht *et al.*, 2009).

## Conclusion

Precision Livestock Farming tools proved effective in quantifying spatial and temporal patterns of goat grazing in a Mediterranean forest rangeland. Seasonal differences in grazing area, mobility, and energy balance reflect strong links between forage availability and animal behavior. Management strategies that combine adjusted stocking rates with strategic supplementation during summer and autumn can help sustain both herd productivity and ecosystem resilience. This approach supports data-driven decision-making for the sustainable use of Mediterranean silvopastoral resources.

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