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# Sheep grazing patterns for better land management: adjusting GPS tracking protocol

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**Key words:** Northeast Portugal; grazing paths; land mosaic; seasonal variation; logging frequency

## Abstract

Small ruminant livestock systems in northeast Portugal are an extensive activity based on daily grazing paths across the landscape. The flocks use multiple patches of multiple land cover types in different ways throughout the year. Shepherd and flock interactions determine the resting and feeding spots utilized by sheep and goats according to the biotic and abiotic conditions. Information about the herding home range is central to managing the land use and vegetation cover and optimizing sheep and goats' productivity in traditional systems. This study's main objective is to contribute to calibrate a shepherding GPS protocol to monitor sheep flocks based on fieldwork in Vimieiro (Mirandela) on a protected area of the European Natura 2000 network. We answer two farmers' and breeders' requests for using GPS collars to monitor the landscape usage by sheep: (1) How closely do collared sheep remain within the flock? (2) How do the collars perform on different logging frequencies to estimate patch occupancy? We analyzed the grazing paths based on three collars' 5-minute GPS positions from winter to summer solstices. We investigated the differences in extent, duration, and frequency data of each collar throughout the season change based on spatial regressions. Results show no significant differences among the three collars ranges. It also indicates that positions collected every 15 and 30 minutes could be adequate. It means that a flock monitoring low cost can be generalized, providing accurate information to manage the pastoral territory and increase the small ruminant's productivity.

## Introduction

Sheep and goat traditional breeds have throughout the centuries provided rural populations with crucial protein levels using local natural resources (FAO 2020). It is particularly true in the mountains regions where they adapted to diverse climates and landscapes. The mountains of Portugal northeast have five ancient breeds of sheep and three of goats that provide essential productive, economic, cultural, social, and environmental functions in a rural landscape of eleven thousand square kilometers (Castro 2016). The livestock system has been resilient to the last half-century' critical rural socio-economic changes where there have been a decline in the rural population and services, then lower prices in the EU extended market, partially due to EU common agricultural policy (CAP). CAP subsidies do compensate for some economic losses, especially for threatened breeds (Franco et al. 2012). However, these traditional livestock industries are under risk. Other functions and ecosystem services provided by the sheep and goat flocks do need to be better understood to help manage those services and ensure they are adequately remunerated.

Over centuries, the small ruminant systems of northeast Portugal evolved, utilising assorted farming remnants that made them resilient to changes throughout time. Local traditional breeds of sheep and goats fit their productive niche constrained by the landscape and the main crops: cereals and cattle. Typically, the shepherds drive flocks of no more than two hundred head around five kilometers of the parish landscape to take advantage of a combination of agriculture by-products and natural vegetation: fallow and agroforestry patches, vegetable leftovers, orchard prunes, woods, and shrublands. Despite their bordering productive role, the shepherding practices supply important ecosystem services: regulation services such as fire risk control; cultural services such as landscape heritage benefits; and supporting services such as nutrient cycling (Marsoner et al. 2018, Castro et al. 2020). These ecosystem services are essential to face climate change threats as recognized by researchers and administration authorities. However, these services are ecosystem-based, and their remuneration requires sheep and goats' heads accounting and the ecosystem usage registration.

The research team has been recording and analyzing the local shepherding routes for more than thirty years (Castro et al. 2004, Castro et al. 2009, Castro et al. 2010). They studied differences between sheep and goats' routes, plant and patches preferences, winter and summer diets, understory and fire risk reduction, grazing and browsing pressure, and vegetation regrows and changes. Recent research has evaluated fire-risk, and

greenhouse gas reduction related to sheep and goats' trampling and feeding in each ecosystem. Twenty years ago, shepherding routes became recorded by GPS systems, and in 2007, our team started using GPS-equipped collars, firstly with memory recording unit, nowadays with GSM and satellite data transmission. The collars data proved effective in recording the shepherding and ecosystem disturbance. Based on these results, the team is now developing a technological solution to record ecosystem usage by the flocks of sheep and goats and integrate it with the CAP Portuguese map services. This solution has to combine low cost and friendly-use equipment for shepherds with precise data and good time transmission for administration. Readability and cost-effectiveness are crucial to success (Maroto-Molina et al. 2019, McGranahan et al. 2018). Therefore, now we evaluated the recording precision – flocks positional maps – against the recording effort – equipment and data transmission costs –. This work's objective was to determine how many collars per flock and what positional data time-interval we need without losing shepherding recording precision.

## Study Site and Methods

We selected a representative flock of north-eastern Portugal's small ruminant systems: a shepherd plus one hundred thirty sheep of local breed Churra Galega that manage the Vimieiro landscape, a small village, in north-eastern Portugal (41°32'N, 7°02'W, 500 m.a.s.l.). The climate is Mediterranean, the mean annual temperature 14°C, and the annual rainfall 520 mm, mainly from October until May (IPMA 2020). Prevailing soil types are nutrient-poor, slightly acidic leptosols and cambisols of granite or schist origin. The flock's daily routes never go more than two kilometers from the shed, covering around 500 hectares of olive groves (35%), oak forests (32%), cereals (22%), shrublands (11%), and pinewoods (2%). The oak species consist of *Quercus faginea*, *Q. suber* and *Q. rotundifolia*, and shrubs species are *Cytisus scoparius*, *C. multiflorus*, *Lavandula stoechas*, *Crataegus monoginea*, and *Cistus ladanifer*. This territory is part of the Romeu site integrating the European Natura 2000 network (PT CON0043), established by the excellent conserved woods of *Quercus suber* and *Juniperus oxycedrus*.

Flock monitoring occurred from December 2020 solstice to June 2021 solstice to cover all seasonal winter to summer variation in sheep diets and vegetation development. We followed the flock with three sets of DOMODIS IP67 GPS receivers and transmitters mounted on collars, housed in 115 x 65 x 40 mm plastic containers together with a DMS-Bat PLUS lithium. Each collar weighed 750 g, and the three selected sheep accepted them without any obvious irritation. We recharged and changed all batteries monthly to record and transmit the three GPS positions every five minutes, enough to trace a spatial grazing pattern of reference. Positional data includes Gauss-Krüger coordinates of latitude and longitude, date, time, and battery status, transmitted to, stored and uploaded from the DOMODIS web platform.

We split and regrouped the original reference dataset into 20 different sub-datasets, considering just one, two, or the three collars, taking all records, or selecting only 15-minute and 30-minute intervals as minimum positioning recording. We create a positioning density map for each sub-dataset in a geographical information system with the **Heatmap** QGIS plugin. They consist of quantitative raster layers by assessing the flock positional records neighborhood around each cell's center based on a user's search radius. The search ratio utilized was equal to the maximum distance between two positional records for each sub-dataset that permits the expression of the widest range of grazing densities. Finally, we used the **r.covar** GRASS module to estimate each sub-dataset positioning density map's correlation ( $r$ ) with the reference's pattern map (all collars + all positional records).

## Results

### *Positioning patterns and similarity*

For 186 days, the collars transmitted 35509 positional records in total (reference dataset), 13811 at 15-minute intervals, and 9613 at 30-minute intervals: collar C1 registered 10170 positions in total, collar C2 11414 positions, and collar C3 13925 positions. The variations among collars' was due to battery performances. Figure 1 shows four of the flock's positioning resulting patterns across the study site. The maximum and minimum gray symbols were standardized to compare the results from a variable number of points and searching radius. It reveals a recurrent pattern on landscape patches utilized by the flock that is more accurate for 5-minute sub-datasets and 3-collar sub-datasets.

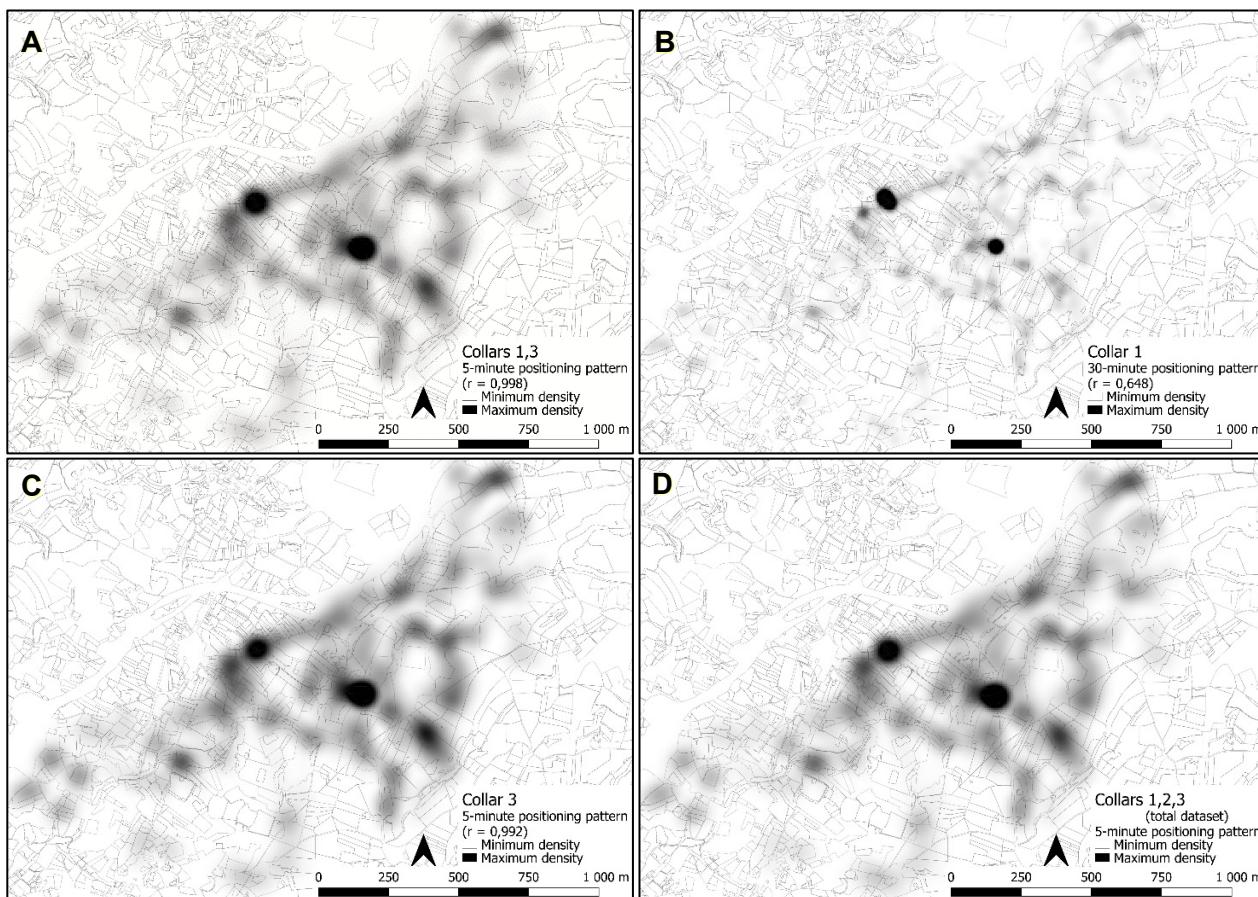


Figure 1 - Raster layers of positioning patterns: collars C1 and C3 each 5 minutes sub-dataset (A), collar C1 each 30 minutes sub-dataset (B), collar C3 each 5 minutes sub-dataset (C), and collars C1,C2 and C3 each 5 minutes - reference dataset (D).

### Costs and accuracy evaluation

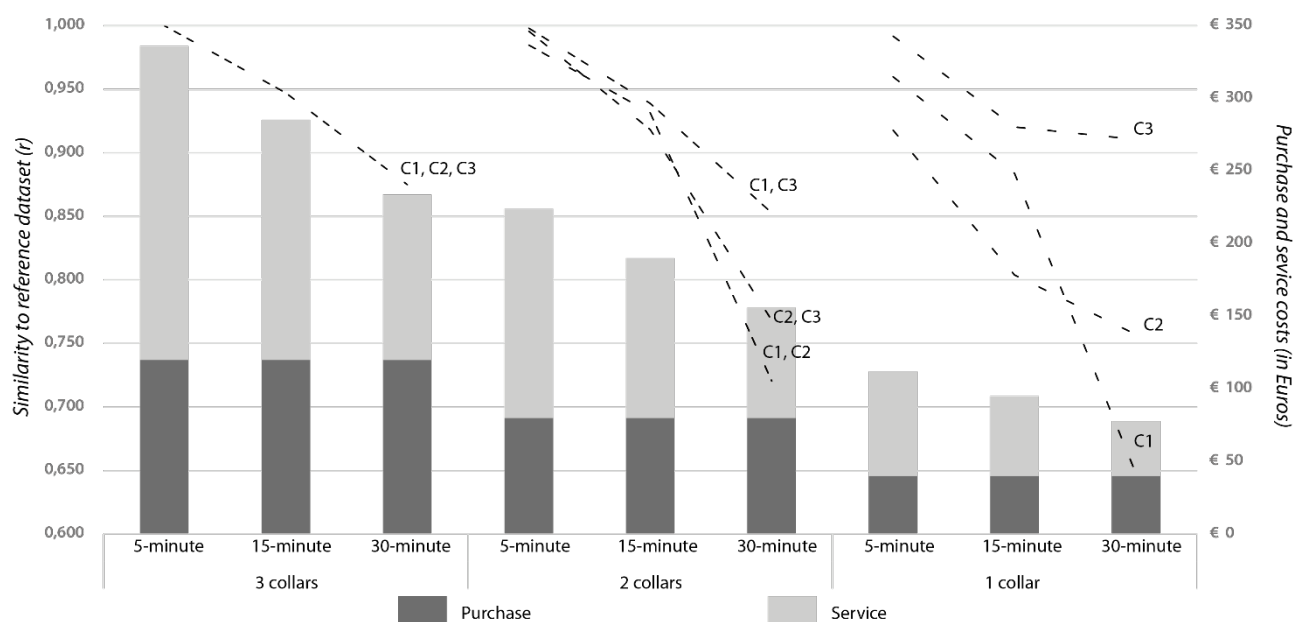
Figure 2 displays the decay in the similarity of each sub-dataset positioning pattern to the reference one and the associated costs per year for each recording options. The correlation  $r$  ranges from 0.99 (sub-dataset C1+C3 and C2+C3, 5-minute intervals, see figure 1-A) and 0.65 (sub-dataset C1, 30-minute intervals, see figure 1-B). The costs include equipment purchase price (€200/collar) and the web platform services agreement (€72/5-minute, €55/15-minute, and €38/30-minute) based on DOMODIS rates and considering a five-year collar usage. The recording options' yearly costs range from €336 (3collars/5-minute intervals) to €78 (1 collar/30-minute intervals). The similarity with the reference dataset quickly drops when we extend the recording interval and not so quickly if we reduce the number of utilized collars. Also, the similarity of positioning patterns with the C2 collar tends to be lower, and those participating by the C3 collar tend to be higher.

### Discussion and Conclusion

Our results indicate that increasing registering intervals and decreasing collars number involve a decline in the flock positioning accuracy as expected. It means that flock displacement on the terrain requires a positioning refinement. According to the similarity declining, increasing registering intervals affects the positioning accuracy more than reducing the number of flock's collars. Nevertheless, the three collars reveal a differential behavior, and C1 and C2 performed worse than C3. Along with records amount, two main reasons could contribute to that: differences in equipment (components, battery life, manufacture) and differences in the animal character within the flock; further research needs to investigate both. After that, if we reduce registering and transmission intervals and rates, we could increase the shepherding assessment feasibility to develop, implement, and generalize a universal assessment procedure.

Shepherding practices provide important ecosystem services, and their cost requires reliability. Our study strengthens the GPS and similar' systems function to evaluate landscape usage by shepherding in north-eastern Portugal accurately. It clarifies how the number of collars and the registration rates affects the system performance. According to our results, we can register the shepherding routes satisfactorily with just one collar if we get short positioning intervals. This means that we can reduce equipment costs significantly. So, the next step is to reduce the operating costs associated with the data transmission services. It demands renegotiating

the web platform services agreement or researching alternative data transmission and logging systems to decrease costs in the future.



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