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ANALYSIS OF MOVEMENT DATA FROM GPS-MONITORED LIVESTOCK GUARDIAN DOGS (LGDS) AT TWO SHEEPFOLDS IN THE NORTH-WESTERN MARAMURES LAND, ROMANIA USING THE KERNEL DENSITY ESTIMATION METHOD. IMPLICATIONS FOR OUTDOOR TOURISM

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Abstract: The Carpathians and other mountainous regions around the world are renowned for their specific landscapes shaped by pastoralism, a millennia-old traditional and sustainable economic system. In Romania, this traditional occupation has an established place within the Romanian culture. In an environment where large predators are present, the livestock owners and shepherds have traditionally relied, and still do, on livestock guardian dogs (LGDs) to protect the flock against carnivores or theft, therefore, the dogs are perceived as an integral component of the traditional pastoral system. However, from late April until the end of September, many outdoor recreational activities like hiking, mountain trail running, or biking overlap with the pastoral calendar, creating a potential for conflict between two, very different categories of landscape users, with recurring incidents happening over the years. In this study, a winter GPS monitoring campaign was proposed, between November 2023 and January 2024 that used GPS professional collars to track the movements of two livestock guardian dogs stationed at two sheepfolds located at their winter bases in the hills at the foot of Ignis Mountains (part of the Romanian northern Carpathians) from north-western Maramureș Land, Romania. The campaign generated point-based spatiotemporal data processed and analyzed in M. Excel and QGIS using Kernel density estimation as the main method to generate metrics and identify potential clusters of LGD activity in their usual environment. The results highlight high observational clusters near the winter folds but also lower observational clusters in areas situated hundreds of meters distance around the main compound, in certain locations. Although temporally limited, the results have the potential to help the understanding of the animal's preferred zone of habitation and substantiate future win-win cohabitation solutions that minimize conflictual encounters between the shepherds and their guardian dogs on one side, as primary land users, and outdoor recreationists as other landscape users.

Keywords: livestock guardian dogs (LGDs), GPS data, sheepfolds, outdoor tourism, landscape users, potential conflicts, cohabitation solutions

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INTRODUCTION

Due to the high degree of natural conservation, rich biodiversity, and diverse landscapes, the Carpathian Mountains are a popular outdoor tourist destination in every season. Due to the high degree of natural conservation, a large part of their surface is under special protection, a status that increases their attractiveness for tourism. The Carpathian cultural landscapes are renowned for pastoralism, a millennia-old traditional and sustainable economic system, best represented by sheepherding. With over 2.5 million hectares of traditionally managed grasslands (Ministry of Agriculture and Rural Development, 2023) of higher quality (Dragoș et al., 2018) in the mountain and alpine areas there is no wonder that even now, pastoralism in general and shepherding in particular continue to represent an important part of the Romanian agricultural and cultural system. The mountain landscapes were shaped over the centuries by this ancient occupation, reflected in documents since the 13th century (Liechti and Biber, 2016), and characterized by the practice of transhumance which involves the movement of the flock from the lowlands to the highlands, according to the season. While doing so, in an environment where large predators are present, the shepherds have traditionally relied, and still do,

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on livestock guardian dogs (LGDs) to protect the flock against large carnivores or theft (Kinka and Young, 2019). The presence of numerous animals for breeds of large size around sheepfolds raises many challenges for other landscape users such as tourists engaged in popular and eco-friendly activities in the mountains of Romania.

Especially during the warmer months of the year, from early May until early October, outdoor recreational activities such as mountain biking, hiking, trekking, or trail running overlap with the traditional pastoral calendar, as most trails intersect the summer grazing domains or zones with permanent sheepfolds used in summer at higher altitudes, or in winter, at lower altitudes. From these challenges, conflict-based situations can arise between a traditional category of landscape users – the shepherd and their large dogs and another, more modern category – the tourists practicing outdoor activities, and require responsible behavior on the part of the tourists to avoid potentially dangerous situations. Most of the time, the encounters end with no harm done, partly because the tourists approach the situation with common sense and appropriate behavior, partly due to the timely intervention of the shepherds.

However, on hiking and biking trails in the mountains and hills with traditional areas used as grazing domains, incidents have happened when tourists were harmed when the livestock guardian dogs, protective of their flock, attacked them (Ivașcu and Biro, 2020). These types of incidents happened on frequented trails from popular mountain ranges such as Făgăraș, Retezat, Bucegi, Apuseni, or Rodnei Mountains, but have occurred also on trails from other, less popular areas in the Carpathians. Various reasons can be invoked to explain these incidents which can be separated into two main categories – behavioral and logistical. Behavioral reasons such as the lack of, or poor training of the dogs, exacerbated by unawareness or the indifference of the shepherds that do not intervene, various veterinary issues on the part of the animals that can contribute to aggressive behavior, previous bad experiences with humans or inappropriate behavior on the part of the tourists. On the logistical side, the lack of touristic warning systems, proper signaling, information, and assistance systems, in print or digital also contribute to the perpetuation of situations where conflict can arise.

We believe that rather than attributing blame or supporting drastic legislative, restrictive, or punitive measures that could compromise this age-old and threatened traditional activity or recreational activities, appropriate win-win solutions can be found that favor the coexistence between shepherds and their large guardian dogs as ancestral landscape users and tourist as modern landscape users. The lack of incentives so far to find a proper solution to the identified problem – the potential for conflict between two categories of landscape users that understand to use the space differently but do not understand each other represents the main motivation behind the present study.

The paper focuses on analyzing the spatial movement of two large guardian dogs from two sheepfolds situated at their winter bases, at the foot of the Igniș Mountains to test the viability of mapping point-based spatial and temporal data. The data were generated from professional GPS devices fitted as collars to dogs and highlighted clusters of movement reflecting preferred areas by the animals. This type of spatial analysis results can be used in the future to substantiate various solutions aimed at minimizing the potential for conflict between these two categories of landscape users.

LITERATURE REVIEW

The pastoral system in the mountains of Romania

The pastoral system in the Romanian Carpathians, like in other parts of the world with a strong pastoral tradition, is generally characterized by mobility and dynamism. Shepherding best represents this system, and relies on local traditional knowledge that has accumulated over centuries of practice. The mobile and dynamic character of shepherding is represented by transhumance, a practice that involves moving the flock according to the seasons between summer and winter grazing domains. There are two transhumance models - the long-distance transhumance, and short-distance transhumance, also known as pendulation. The long-distance transhumance is still practiced in some areas of the country, like Mărginimea Sibiului, but in recent years, is practiced with a lesser intensity and on smaller areas (Velcea et al., 2016; David et al., 2021; Săgeată et al., 2023). One of the reasons for this situation is that the practice has become harder and costlier due to land fragmentation for instance (Huband et al., 2010; O'Brien and Crețan, 2019). The pendulant transhumance is the predominant model all over the country, especially the mountainous areas, as it is a necessity for small households to continue to produce and support themselves (Huband et al., 2010). This model is similar to the one practiced in the alpine regions (Luick, 2008). Usually, short-distance transhumance means that the shepherds move the animals between homes and their mountain pastures with the avoidance of main roads and building areas (Juler, 2014). It is considered that such pastoral systems based on pendulation are conserving large areas of semi-natural grassland in the Carpathian mountains (Young et al., 2019).

The livestock guardian dogs (LGDs) as a component of the pastoral system

The livestock guardian dogs can be viewed as cultural icons in areas with strong pastoral traditions as they have been an integral component of the traditional system (Linnell and Lescureux, 2015), and have been used for centuries to protect livestock, especially sheep (Young et al., 2019). The dogs proved to be an effective method of protection of livestock and predator impact reduction for centuries not only in Romania, but also in Europe (Allen et al., 2016) and other parts of the world. In countries with advanced agriculture or a different approach to animal husbandry, the use of livestock guardian dogs has been contested as they do not aggregate with modern practices or territorial characteristics (Allen et al., 2016), or are deemed a threat to biodiversity. This claim has been challenged by studies that showed that the dogs focus on protection and tend to avoid confrontations with predator animals (Yilmaz et al., 2015) by staying close to the flocks.

In Romania, usually, a large flock can comprise up to 700 sheep. In these conditions, it is almost impossible for shepherds to work without the help of guardian dogs to protect the sheep and alert the shepherds of the dangers. As the

Carpathians shelter the highest number of large carnivores like brown bears, wolves, and lynxes in Europe (Popescu et al., 2016; Rozylowicz et al., 2017), this means that it is common practice for a single flock to be protected by 4-7 or more dogs. There are instances when more than 15 dogs can be found at a single sheepfold alone, as is the case at one of the two sheepfolds involved in this study. In Romania, there are at least four typical breeds of livestock guardian dogs of large size, that can weigh between 50 and 80 kilograms. Three of the breeds are internationally recognized (the Romanian Mioritic Shepherd, the Romanian Bucovina Shepherd, and the Carpathian Shepherd) and are present at almost all sheepfolds across the country due to their excellent protection capabilities. In recent years, Asian breeds have been introduced at many sheepfolds, including at the ones from mountainous areas of Maramureș Land. These breeds include the notoriously aggressive and territorial Kangal and the Caucasian Shepherd, which can pose serious challenges in tourist areas (Ivașcu and Biro, 2020).

The livestock guardian dogs (LGDs) and tourists

From late April until the end of September, the mountain outdoor activities season is in full and overlaps with the pastoral calendar, hence the potential for conflict between the dogs protecting the sheep on their grazing domains and the tourists or outdoor sports enthusiasts that frequent the same areas. The pack effect generated by a large number of dogs around a single flock that instinctively behave to protect it can become problematic for other landscape users. In situations like this, the dogs can become an issue (Gehring et al., 2010) as they enter into conflicts with the people that use the spaces they roam for recreative purposes, attacking and sometimes bitting hikers, joggers, and mountain bikers (Mosley et al., 2020). Usually, when people become aware of the presence of the sheep and the dogs, tend to avoid the area by choosing to move away on different paths. However, this approach does not represent a solution that works all the time, and when encounters of this type end with injuries, unfortunately, the incidents are not reported specifically as such to medical authorities, and therefore, no reliable statistical database is available to glimpse the scale of the problem.

METHODOLOGICAL FRAMEWORK

Description of the study area and the sheepfolds involved

The study area is situated in the western part of Maramureș Land, in an area with complex relief characteristics such as Igniș and Gutâi Mountains, that have been studied about other geographic phenomenologies (Ilieș et al., 2022). Maramureș Land is a well-defined land type region situated in northern Romania, with low population density, a rich diversity of landscapes and habitats, strong identitarian features, and a high reliance on local and traditional knowledge that has accumulated over the ages. In medieval documents concerning the area of Maramureș, animal husbandry in general and shepherding in particular are more frequently mentioned than agriculture (Ilieș, 2007), as was the case in the area of Maramureș Mountains from the north-eastern side (Hotea, 2019), thus highlighting the importance of the occupation since those times.

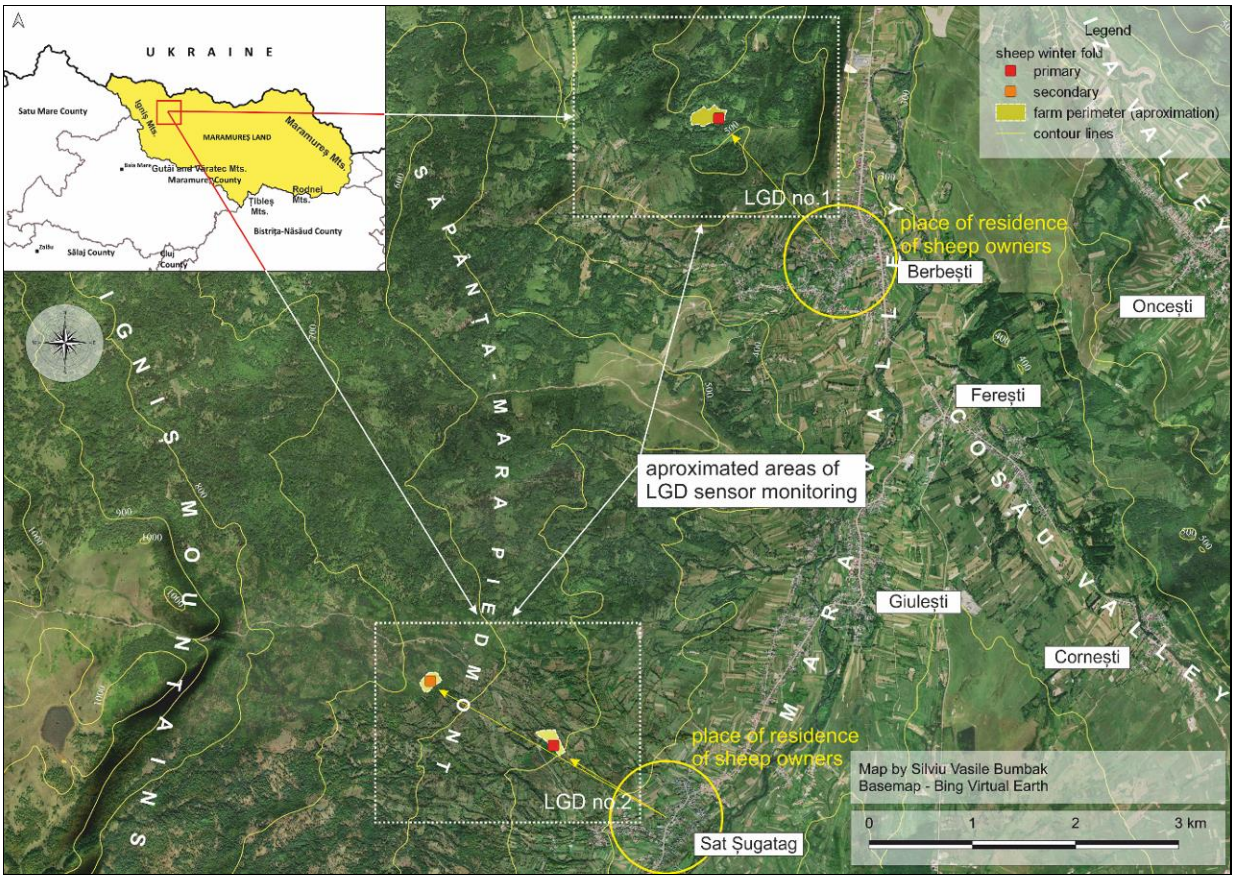

Figure 1. The area of interest and the locations of the two winter folds that participated in the study

The study was conducted at the winter folds of two sheep owners – the Codrea family from the village of Berbești and the Vraja family from the village of Sat Șugatag respectively. The families rely on shepherding as their main source of income. The winter folds are situated near the places of residence (1-2 kilometers distance), in the piedmont hills of Mara-Săpânța, at the foot of Igniș Mountains, a plateau-like volcanic range with altitudes between 1000 and 1300 meters. Both sheepfolds have their summer grazing domains up on the volcanic plateau. In winter, they establish themselves lower (see Figure 1), as it is the custom of short-distance pendulant shepherding, on family-owned land. The Vraja family from Sat-Șugatag uses two locations as winter fold, one situated at around 500 meters altitude and another, smaller, situated higher, at around 650 meters.

The livestock guardian dogs involved in the study, selection criteria

Both families own over 150 sheep and keep around 10 dogs with them. The dogs are livestock guardian dogs of the consecrated breeds. A recently bought pup (at the time of the first phases of the study) from the Kagal breed was spotted among the dogs of the Codrea family, while the Vraja family owes only dogs from the Romanian breeds. As there were only two GPS collars used for this study, one dog from each fold was selected in agreement with the representatives, based on certain criteria – the dogs should be males, between 2 and 6 years of age, with a strong bond and a known history of keeping closer to the sheep over time, especially during the movement of the flock on grazing domains.

The first criterion was established after the family representative stated that the mobility of the dogs increases in the mating season with the females more prone to farther away from the fold. The male dogs could follow and the chances that the dogs to go farther away from the fold are high in this period, a situation that can become dangerous, as the large carnivores tend to get closer to the fold if they do not get the scent of the dogs nearby. The age and bonding criteria were established as the dogs are in their prime and already fully bonded with the flock at this age. The last criterion was based on observations from the shepherds. Finally, two livestock guardian dogs were selected – a two-year-old white male Carpathian shepherd among the Codrea family dogs (referred to as LGD no. 1) and a three-year-old black, neutered Bucovina shepherd male, among the Vraja family dogs (referred to as LGD no. 2).

Instruments and workflow

The methodology of the study comprises several working stages that span several months, and are described below (see Figure 2). After the preparation of the research design, selection of GPS devices, and participants for the study, in the second half of November, dogs from the two sheepfolds were fitted with collared GPS trackers. For this study, two professional GPS trackers from the Spanish-based Digitanimal project entity, that works with various research centers and experimental precision livestock farming entities (Navarro et al., 2021). The GPS devices are designed for livestock but are suited also for livestock guardian dogs. The connectivity is assured either through the Sigfox (IoT) technology or through the mobile GSM technology. During the consultation process with the company's representative, it was established that considering the locations of the two winter sheepfolds in question, the GSM option is more suitable. The under 300 grams GPS trackers have sensors for movement and temperature, and sensors for activities and alerts. The sensors gather data every 30 minutes. For the location sensor, the radius CEP (circular error probable) is under 2.5 meters, which was technically acceptable from the author's perspective. After the arrival of the devices, access to a dedicated platform was granted in order to monitor in real-time the device's sensors and to download the location data in the desired formats – in this case in CSV format. Access to the platform was necessary because the data sent by the sensors was stored on the company's servers. The other functionalities, although valuable, were not used in this study.

The trackers were fitted on the selected dogs accordingly and using the dedicated accessories. The first collar was fitted on the Carpathian Shepherd from the Codrea farm on 15 November 2023, while the second tracker was fitted on the Bucovina Shepherd from Vraja farm seven days apart, on 22 November 2023. Both trackers were removed on 10 of January 2024, as per agreement with the representatives of the two farms, totaling 57 days of monitoring.

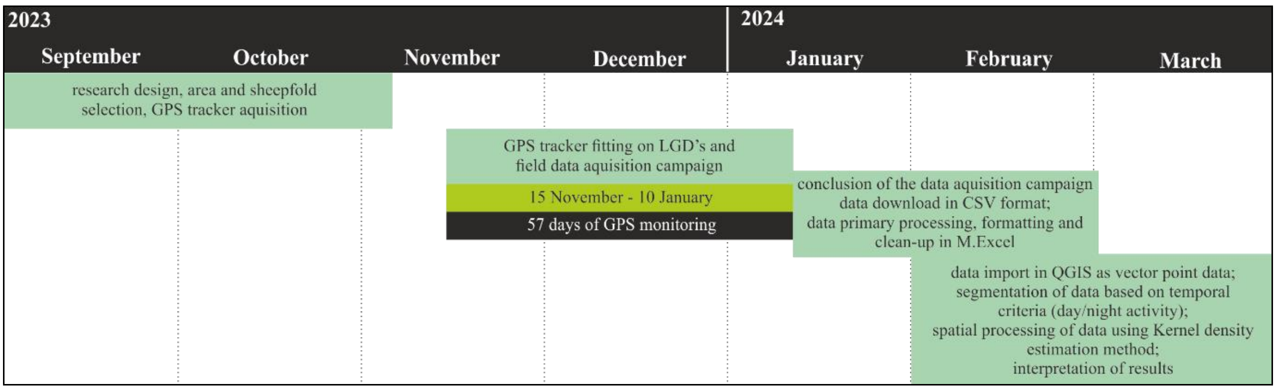

Figure 2. Timeframe and main methodological stages of the study

Procedures and methods

At the end of the field monitoring campaign, once the devices were removed, the targeted data for the time frame 15 November 2023 – 10 January 2024 was downloaded in CSV format (two CSV tables, one for each LGD) as the primary data processing was made in M.Excel. This format for data downloading was chosen as it is compatible with QGIS for creating point-based vector data representing the locations of the animals every 30 minutes.

The data was filtered to eliminate the time intervals at both ends that involved the GPS tracker fitting and removal procedures and the intervals in which the trackers were not on site. Also, in this stage, a formatting procedure was necessary to ensure that one of the most important columns in the table containing the date and time intervals of each location was in the date-time format requested for use in QGIS.

Another filtering procedure involved the labeling of the data in daytime and nighttime data based on established hourly intervals. This step was considered necessary, as the recreational activities done in outdoors usually occur during daytime hours. The labeling was done by creating a new attribute column using the If function in M. Excel and specific time intervals as criteria (daytime from 06:00 AM to 09:59 PM / nighttime from 10:00 PM to 05:59 AM).

The next stage assumed the import of the M. Excel data spreadsheets into QGIS for further processing and analysis over a satellite image (Blaga et al., 2023) as a base map from the Bing web mapping service. The import process assumed the conversion of the Excel spreadsheet into a discrete data set by creating a vector point layer representing the locations every 30 minutes of the LGD's using the decimal coordinates. As the project needed a CRS (coordinate reference system) that recognized the metric system, to determine parameters for obtaining proper Kernel estimates, the WGS 84 pseudo-Mercator projection was selected, as it is a global system easy to aggregate with other third-party spatial data. Therefore, the obtained vector point layers were reprojected in the desired CRS. The two vector point layers were segmented using the calculator function in the attribute tables of the layers to separate the day-time observations from the night-time observations. The procedure ended with four new vector point layers created (two for each LGD), for the day-time and night-time respectively. As the main objective of the study was to analyze and identify potential zones as clusters from LGD movement data, several spatial algorithms were used. First, a home range analysis was performed for both the daytime and nighttime observations using the minimum bounding geometry algorithm. The algorithm shows the maximum extent of the areas the two LGDs have used in the timeframe of the study, during the day and the night. This first approach was useful to estimate and compare the spatial areas in which the two dogs have been observed in both instances. However, this algorithm does not show the areas in which the animals have spent more time. Therefore, a kernel density analysis was performed to obtain a type of result indicating potential clusters of preferred areas used by the dogs.

For the Kernel density estimation, the density analysis tool was used, among other QGIS algorithms that work similarly. For the analysis, only the vector point data representing the day-time observations were taken into account as these were considered the most important concerning potential recreational activities in the area. The Kernel density estimation method is a non-parametric model that creates an intensity distribution from a data sample with no model assumption in mind. For geographical studies, the method will generate a spatially distributed model in the form of a density raster layer from point vector data by calculating the number of points in certain locations and thus being useful in identifying hotspots and clusters (Lloyd, 2010). The algorithm requires a vector layer as input and the specification of several important parameters – the pixel cell size (established at 50 meters) and the radius, used for defining areas to calculate local densities around points. To establish a proper radius for kernel calculations, the equation proposed by Fortheringham was used (Fortheringham et al., 2000). The simplified version of the equation is described below:

(1) R= ((2/(3N))1/4)*SD where R – radius; N – total number of received observations (vector points); SD – standard distance. The SD was computed using the standard distance tool in QGIS for each layer representing the daytime LGD activity.

Following the parameter input the Kernel density estimations two raster layers were generated for the two vector point layers representing the day-time activity of the LGDs.

RESULTS AND DISCUSSION

After the fitting of the GPS collars in 15 November (LGD 1) and 22 November (LGD 2) respectively, the trackers were followed via the dedicated Digitanimal web application. After the first day of observations, it was noted that the second collar, fitted to the LGD no.2 from the Vraja farm, received messages with a much lower frequency than the first collar. After 19 days of monitoring, on 10 December 2023, the signal from the second tracker was lost entirely. The team chose not to intervene and assess the situation after the monitoring campaign concluded on 10th January. The signal from this device was not recovered and after the collars were removed at the end of the monitoring campaign, upon inspecting the devices, no physical damages were observed. One hypothesis follows the quality of the signal from the mobile operators available in the area influenced by the topography of the terrain, land cover, and other terrain or technical-related elements. The device fitted on the LGD no. 1 from Codrea farm performed well on the entire duration of the monitoring campaign and the data received from this device were used as a baseline standard for symbolizing the raster values obtained through the kernel density estimation method for both cases.

Data distribution and derived parameters

Once the terrain stage was concluded, the data were processed firstly in M.Excel. The data were cleaned to eliminate the time intervals at both ends of the field monitoring campaign, from the day in which the trackers were fitted on the dogs (15 November 2024 for LGD 1 and 22 November 2024 for LGD 2) and the devices were found at other locations, and the last day of the campaign (10 January 2024), when the devices were removed. For 15 and 22 November respectively, the observations received before noon were removed. For 10 January, all observations after 04:00 PM were removed. The primary analysis of the data that followed after the CSV data files were imported into QGIS and segmented into day and night vector layers, assuming the use of the minimum bounding geometry tool for a first estimation of home range for both day and night data sets. Even though the kernel density estimation method by itself calculates the home range, it was considered appropriate to compute separately the maximum extent of the areas the two LGDs have used in the timeframe of the study (Figures 3 and 4). The home range results indicate differences in area coverage between the two dogs, especially during the day. Firstly, LGD no.1 covered an area twice the size of LGD no.2 (Figures 3 and 4), with over 6 sqkm compared to just over 3sqkm.

Table 1. Overview of GPS devices performance and key parameters used for spatial analysis captions (photo – BSV)

GPS trackers + accessories	**tracker fitted on LGD 1**	**tracker fitted on LGD 2**
		
length of sensor monitoring	57 days	19 days
GPS tracker temporization	every 30 minutes	every 30 minutes
N	1410 obs.	289 obs.
N_{day} *	**1016 obs.**	**223 obs.**
N_{night}	394 obs.	66 obs.
Homerange (day)	6,61 sqkm	3,18 sqkm
Home range (night)	0,12 sqkm	0,08 sqkm
SD_{day} *	**970 m**	**930 m**
R_{day} (Fortheringham's formula) *	**155,25 m**	**365,75 m**
*data used for kernel density estimations		

There is also a clear difference between daytime and nighttime behavior. For the time of the year covered by the study, the dogs demonstrated considerable levels of mobility during the day, but is can be inferred that the level of mobility and the area covered were influenced by the decisions the shepherd made while selecting the appropriate areas for grazing.

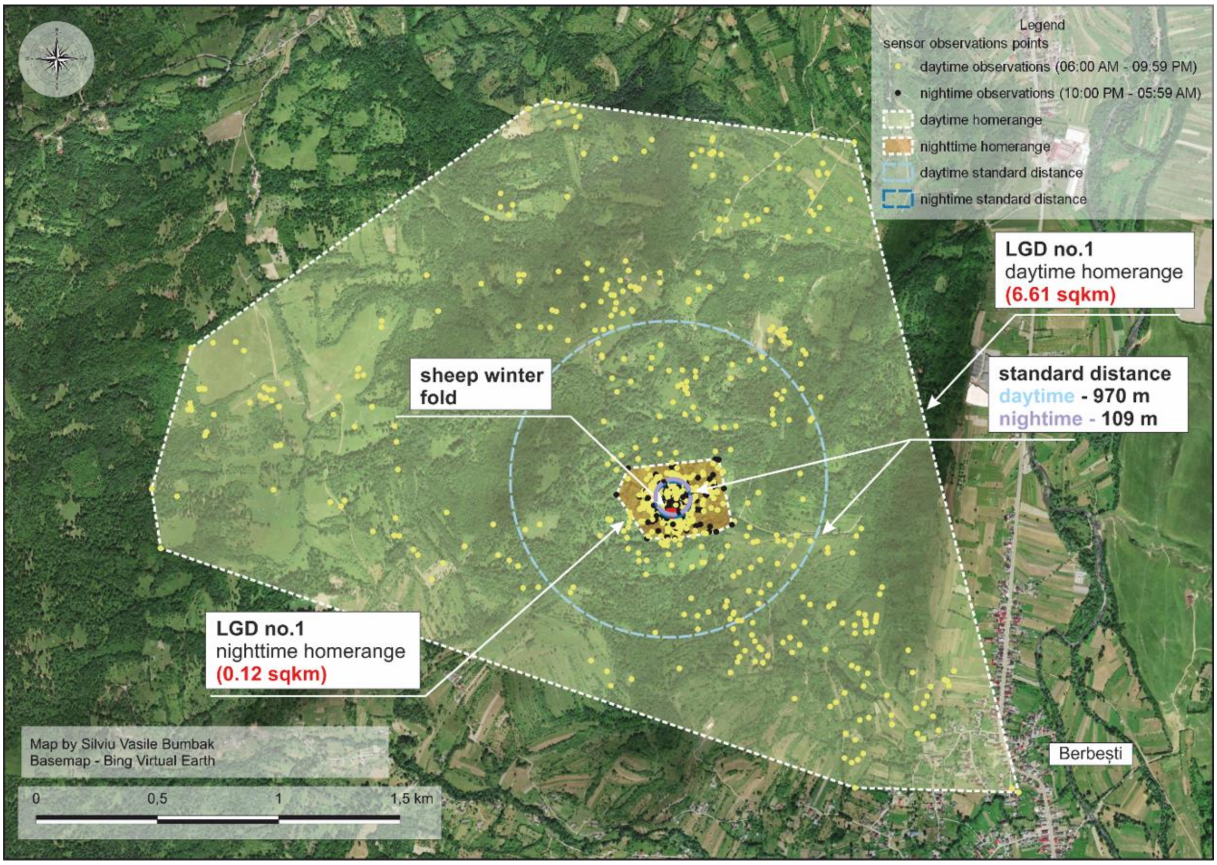

Figure 3. Point-based location of the sensor observations for LGD no. 1 and derived parameters

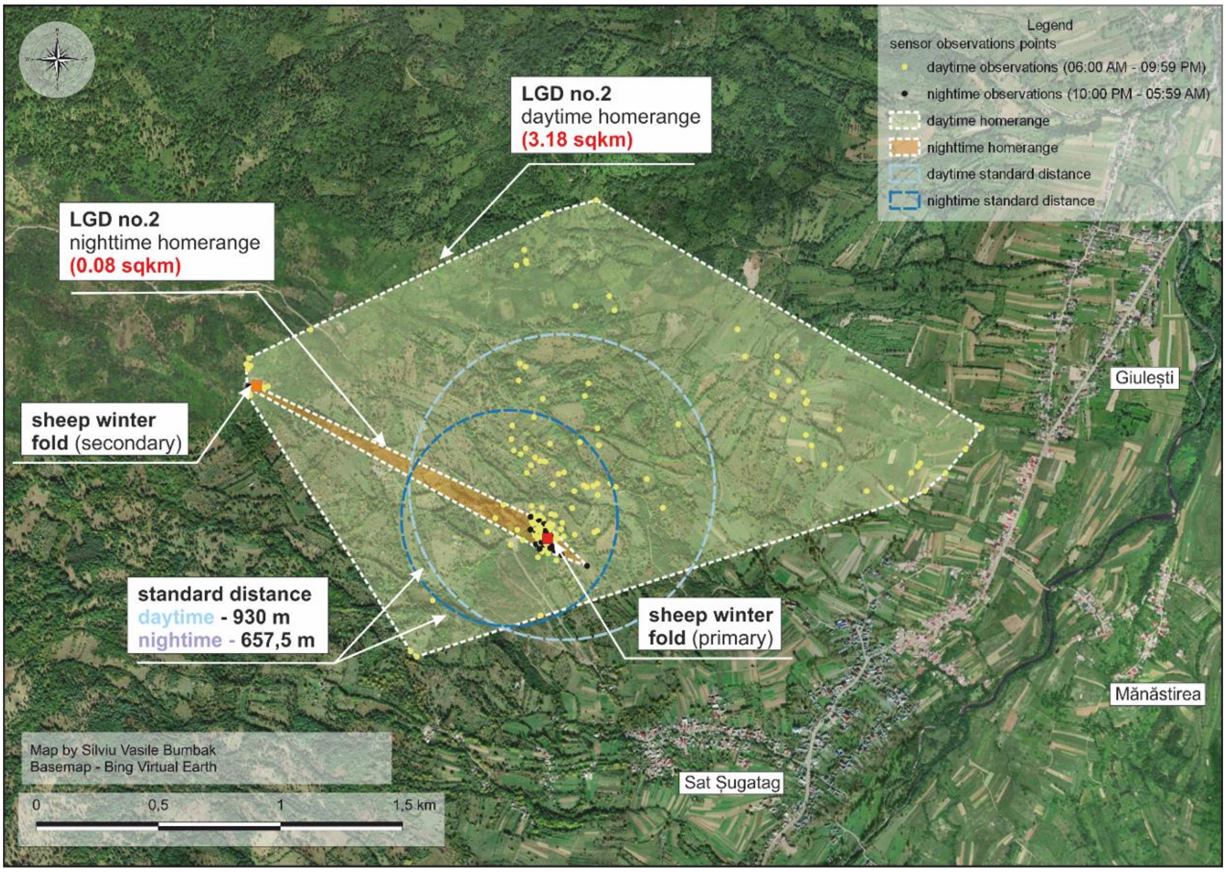

Figure 4. Point-based location of the sensor observations for LGD no. 2 and derived parameters

During the night the values are similar, and highlight the fact that both dogs spent the nights at or near the sheepfolds. Even if the number of observations received through the sensors was lower in the case of LGD no. 2, the absence of "stray" location points during the night indicated the fact that the dogs indeed spent the nights closer to the fold. In the case of LGD no. 2, the data shows time spent at the other winter fold location (secondary winter sheepfold in Figure 4), meaning that in the time interval for which data are available, the flock moved between the folds at least once and spent at least one night at the second location. It can be assumed that the other dogs at each sheepfold follow a similar behavior and that the point-based locations indicate the presence of the majority of the dogs. Also, since one of the criteria used for selection involved choosing an LGD that follows the flock as it moves around during the day with the shepherds, it can be assumed that the locations are an indication of sheep presence. These two aspects are hard to verify in the absence of data from collars attached to other dogs from the packs but also to sheep.

The standard distance, computed through a dedicated algorithm available in the QGIS Plugin repository, by itself can offer valuable information regarding the behavior of the dogs during the day and night. The standard distance measures the compactness of a distribution of points (Mitchell and Scott Griffin, 2005) around a center. In this case, the centers are represented by the locations of the sheepfolds, which can also help understand the spatial behavior of the animals. In the case of LGD no. 2, the nighttime standard distance value (over 600 meters) presents a more dispersed pattern. The pattern was influenced by the recordings of time spent at the second winter fold which is situated at approximately 1.5 kilometers distance from the main winter fold, therefore, it is considered that the computations should have taken into account a supplementary segmentation of the data based on the locations around the two winters folds. In the case of LGD no. 1, the standard distance value is reduced (just over 100 meters) suggesting a compact distribution that highlights that during the night, at least for the time interval of the study, the dog did not wander far from the sheepfold.

Daytime kernel density estimations

Considering the compact behavioral patterns of the dogs during the night, that remained close to their winter bases, it was firstly debated and then decided as appropriate to focus the kernel density estimations only on the daytime data as daytime hours coincide with recreational activities done outdoors. The method was applied using only the vector point layer encompassing the daytime data, even though a weighted value approach to the original vector layers could have been employed (Pathmanandakumar et al., 2023). The kernel density estimations were computed using a 50 by 50-meter cell size and the calculated radius and standard distance values obtained previously.

Each raster cell represents the number of daytime observations recorded at that location. For comparison purposes, the results for the daytime activity of LGD no. 2 (maximum of 120 observations/raster cell), were symbolized using the scale of values for the daytime activity of LGD no.1 (maximum of 280 observations/raster cell).

After the initial computations and analysis, the data showed disparities between the high clusters of observations recorded in the proximity of the winter bases and the nearby areas. This result was to be expected, considering the previous results obtained using the standard distance tool, which indicated a clustered pattern centered around the winter folds at both sites. A threshold with a minimum of 5 observations per raster cell was established to identify potential clusters outside the areas near the winter folds, where the values are much lower. The minimum of 5 observations represents an indicator of a preferred area highlighting either occasional overlappings of data in different days, multiple returns in the same area, or simply a higher amount of time spent at a certain location. This aspect is again hard to determine in the absence of a higher amount of data comprising a much larger interval. However, this spatial information is useful for identifying areas farther away from the winter folds that are still frequented by the sheep and dogs and could be perceived as problematic for outdoor activities. The threshold was used again in generating contour lines that highlight more evidently the areas with at least 5 observations. These areas are considered lower observational clusters and are situated hundreds of meters distance from the main compounds (Figures 5 and 6).

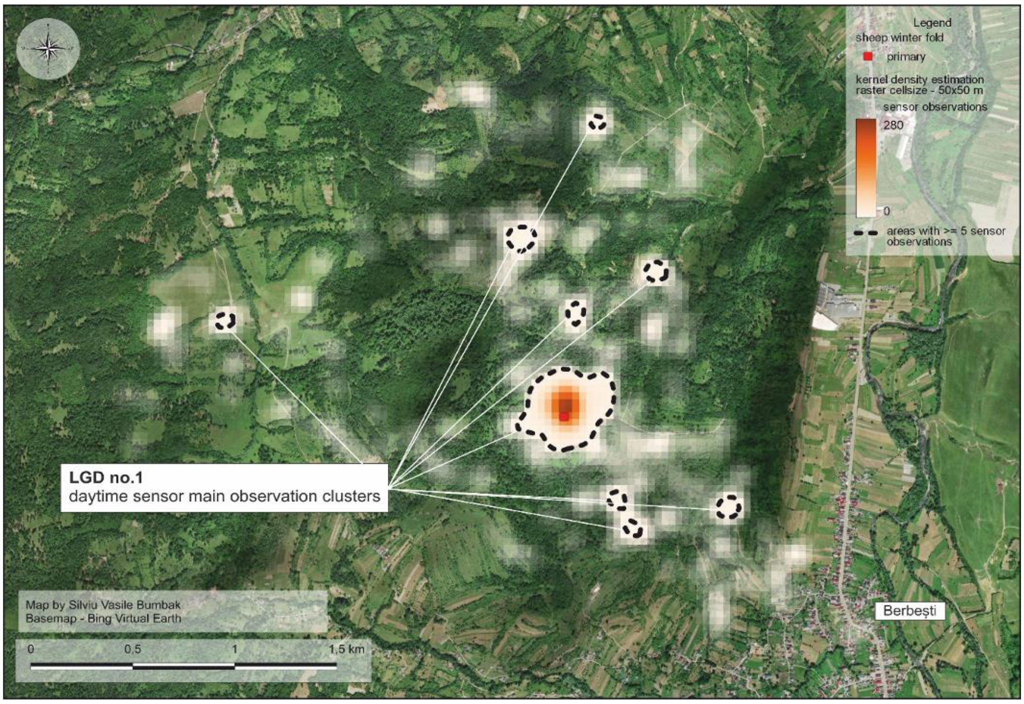

Figure 5. Clusters of daytime activity based on sensor observation for LGD no. 1

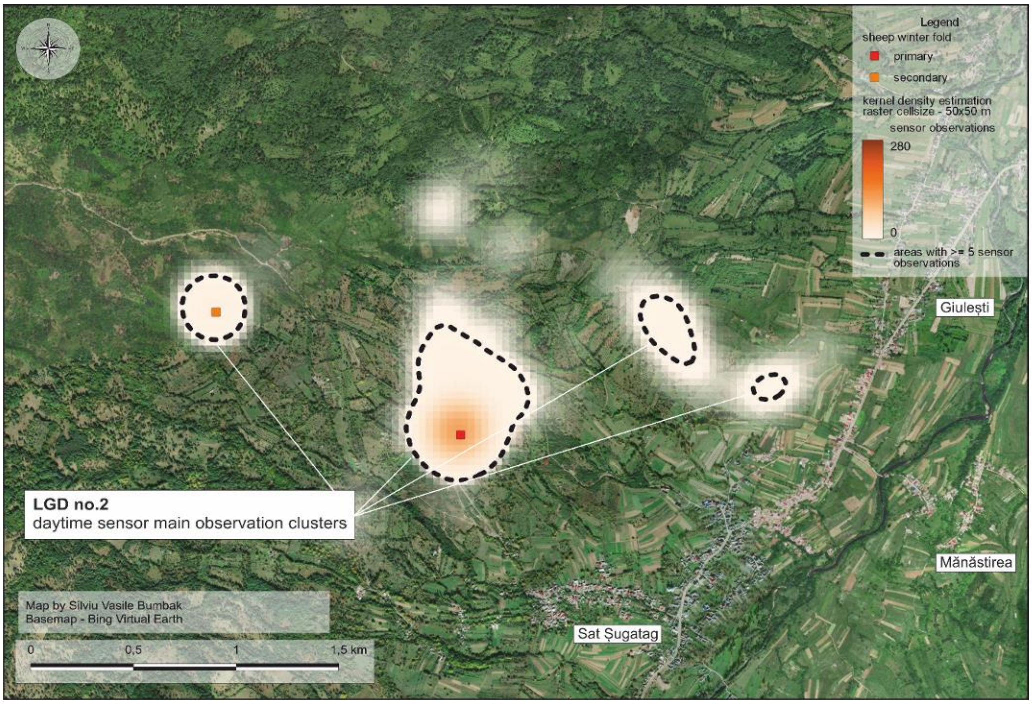

Figure 6. Clusters of daytime activity based on sensor observation for LGD no. 2

In the case of LGD no. 1 (Figure 5), outside of the main cluster centered around the winterfold, eight secondary clusters of at least 5 observations were identified. The clusters cover small areas of up to 1.5 hectares. Their dispersed distribution and small size suggest that the flock and dogs moved constantly from pasture to pasture, indicating a faster movement pattern, with shorter amounts of time spent on each grazing spot. In the case of LGD no. 2 (Figure 6), three zones of this type were identified outside the main cluster, with one being centered around the second winter fold.

These clusters cover large areas, between 2 and 6 hectares, and indicate a different movement pattern that suggests a different approach on the part of the shepherds concerning the choice of pasture and the amount of time spent grazing it. In the case of LGD no 2, the entire flock spent more time on those three areas, which were, except the cluster identified around the secondary winter fold, probably strategically selected.

Considering the time of the year in which the field monitoring was conducted, with shorter days, and wintry conditions the high observational clusters identified in both situations near the winter bases indicate that the sheep and the dogs spent just a couple of hours per day outside their main premises and could be found occasionally in other locations.

CONCLUSION

Even though the study was undertaken outside the main pastoral season and encompassed a limited time interval, it was possible to identify clustered patterns of movement in both situations. For the analyzed time interval (15th November – 10th January), two main clusters were identified around the winter folds, suggesting that the dogs tend to stay at or closer to their bases even during the day, where they spent the majority of the time.

For the two LGDs involved in the study, important differences between their movement patterns were found. The differences concern especially the daily pattern of movement of the two livestock guardian dogs, where differences have been observed even though both originate from two sheepfolds found in proximity of one another, that use spaces with similar characteristics for their sheep. The many factors that could be taken into account to explain these findings represent another fertile research field and highlight the potential for expansion of the present study. Again, in order to achieve such goals, future studies should cover more sheepfolds and, preferably, from areas with different characteristics, even if selected from the same region. These findings have the potential to be used in the design of tools that could inform a decision-making process on behalf of the tourists or recreationists who have the desire to visit the area but are afraid or unaware of the dangers the dogs could pose to them. Instead of choosing not to visit the area altogether, why not decide how best to move around while avoiding the zones with the highest probability of finding sheep and dogs and reducing the chances of problematic encounters? To achieve such an objective, further research comprising a larger time frame and preferably the summer pastoral calendar is needed in this direction.

This study represents a preliminary phase from a much larger, future research that would span several years and encompass a higher number of sheepfolds from Maramureș Land. However, the future research will have to adapt the research design in order to monitor both sheep and, preferably, more than one dog from each sheepfold. In this way, positive or negative correlations and key parameters about the movement of the flock and dogs could be assessed.

The study had several limitations that will have to be addressed by the future research, before the next field campaign. Firstly, the issue of device integrity and level of resistance to elements and other miscellaneous factors. From two devices, one performed well for the entire duration of the field stage, while the other lost its transmission capacity after 19 days. A causal explanation for this event will be formulated after the device in question is inspected and discussed with the company representatives. Secondly, the issue of signal acquisition through the GSM technology (the one used in this study) in the selected areas from the Mara-Săpânța Piedmont. The team did not use an antenna and relied solely on the GSM networks. Even though the GSM operators offer signal coverage in the area in question, in both cases, the total number of observations (N) could have been higher. The number of observations could be the result of possible influences of the topography, land cover, and other terrain-related elements, and require a distinct assessment to understand the landscape influences.

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REFERENCES

Allen, L.R., Steward-Moore, N., Byrne, D., & Allen, B.L. (2016). Guardian dogs protect sheep by guarding sheep, not by establishing territories and excluding predators. *Animal Production Science, 57*(6), 1118-1127. https://doi.org/https://doi.org/10.1071/AN16030

Blaga, L., Ilieș, D.C., Wendt, J.A., Rus, I., Zhu, K., & David, L.D. (2023). Monitoring forest cover dynamics using orthophotos and satellite imagery. *Remote Sensing, 15*(12), 3168. https://doi.org/https://doi.org/10.3390/rs15123168

David, L., Semuc, I., Vlad, I., Șerban, C., Săvulescu, I., Vrăjitoriu, A., Săvescu, I., & Munteanu, C. (2021). *Transhumanța carpatică a oilor țurcane. Continuitatea elementelor arhaice pastorale în mileniul al III-lea [The Carpathian transhumance of turcana sheep – The continuity of archaic pastoral elements through the 3rd millenia]*. Bucharest, Romania: Ethnological Publishing House.

Dragoș, M., Dragomir, N., Horablaga, M., & Rechițean, D. (2018). Production dimension and potential of permanent grasslands of Romania in relation to animals growth. *Scientific Papers - Agronomy series (Lucrări Științifice - seria Agronomie), 61*(2), 105-108. Retrieved from https://www.uaiasi.ro/revagrois/PDF/2018-2/paper/20.pdf

Fortheringham, S.A., Brunsdon, C., & Charlton, M. (2000). *Quantitative Geography: Perspectives on Spatial Data Analysis.* London, UK: Sage.

Gehring, T.M., VerCauteren, K.C., & Landry, J.M. (2010). Livestock Protection Dogs in the 21st Century: Is an Ancient Tool Relevant to Modern Conservation Challenges? *Bioscience, 60*(4), 299-308. https://doi.org/https://doi.org/10.1525/bio.2010.60.4.8

Hotea, M. (2019). *Munții Maramureșului - Studiu de geografie umană (The Maramureș Mountains - study of human geography).* Cluj-Napoca, Romania: Cluj University Press.

Huband, S., McCraken, D., & Mertens, A. (2010). Long and Short Distance Transhumant Pastoralism in Romania: Past and Present. *Pastoralism: Research, Policy and Practice, 1*(1), 55-71.

Ilieș, G. (2007). *Țara Maramureșului - Studiu de geografie regională [Land of Maramureș - Study of regional geography].* Cluj-Napoca, Romania: Cluj University Press.

Ilieș, G., Ilieș, M., Hotea, M., Bumbak, S., Hodor, N., Ilieș, D.C., Caciora, T., Safarov, B., Morar, C., Valjarević, A., Berdenov, Lukić, T., Mihajlović, M., Liudmyla, N., & Vasic, P. (2022). Integrating forest windthrow assessment data in the process of windscape reconstruction: Case of the extratropical storms downscaled for the Gutai Mountains (Romania). *Frontiers in Environmental Science, 10*. https://doi.org/https://doi.org/10.3389/fenvs.2022.926430

Ivașcu, C.M., & Biro, A. (2020). Coexistence through the Ages: The role of native livestock guardian dogs and traditional ecological knowledge as key resources in conflict mitigation between pastoralists and large carnivores in the Romanian Carpathians. *Journal of Ethnobiology, 40*(4), 465-482. https://doi.org/https://doi.org/10.2993/0278-0771-40.4.465

Juler, C. (2014). După Coada Oilor: Long-distance transhumance and its survival in Romania. *Pastoralism: Research, Policy and Practice, 4*(4), 1-17. https://doi.org/https://doi.org/10.1186/2041-7136-4-4

Kinka, D., & Young, J.K. (2019). Evaluating domestic sheep survival with different breeds of livestock guardian dogs. *Rangeland Ecology & Management, 72*(6), 923-932. https://doi.org/https://doi.org/10.1016/j.rama.2019.07.002

Liechti, K., & Biber, J. (2016). Pastoralism in Europe: characteristics and challenges of highland-lowland transhumance. *Rev Sci Tech, 35*(2), 561-575. https://doi.org/https://doi.org/10.20506/rst.35.2.2541

Linnell, J.D., & Lescureux, N. (2015). *Livestock guardian dogs: Cultural heritage icons with a new relevance for mitigating conflicts.* Norwegian Institute for Nature Research. European Commision. https://lciepub.nina.no/pdf/636097452011012523_Linnell%20NINA%20livestock%20guarding%20dogs_web.pdf

Lloyd, C. (2010). *Spatial data Analysis: An Introduction to GIS Users.* Oxford, UK: Oxford Press.

Luick, R. (2008). Transhumance in Germany. *European Forum on Nature Conservation and Pastoralism*, 1-16. Retrieved from https://www.efncp.org/download/Swabian_Alb_F_F_Download.pdf

Ministry of Agriculture and Rural Development. (2023). *Romania's Mountain Natural Resources: Technical Assessment Report.* Retrieved from https://www.madr.ro/docs/poca/2024/5.-ENG-Mountain-Area-Natural-Resource-Assesment-Report-A4.3.pdf

Mitchell, A., & Scott Griffin, L. (2005). *The ESRI Guide to GIS Analysis, Volume 2: Spatial measurements and statistics.* Redlands, USA: ESRI Press.

Mosley, J.C., Roeder, B.L., Frost, R.A., Wells, S.L., McNew, L.B., & Clark, P.E. (2020). Mitigating Human Conflicts with Livestock Guardian Dogs in Extensive Sheep Grazing Systems. *Rangeland Ecology & Management, 73*(5), 724-732. https://doi.org/https://doi.org/10.1016/j.rama.2020.04.009

Navarro, J., Martín de Diego, I., Carballo Pérez, P., & Ortega, F. (2021). Outlier detection in animal multivariate trajectories. *Computers and Electronics in Agriculture, 190*. https://doi.org/https://doi.org/10.1016/j.compag.2021.106401

O'Brien, T., & Crețan, R. (2019). The role of identity in the 2015 Romanian shepherd protests. *Identities: Global Studies in Culture and Power, 26*(4), 470-488. https://doi.org/https://doi.org/10.1080/1070289X.2017.1400322

Pathmanandakumar, V., Goh, H., & Chenoli, S. (2023). Identifying potential zones for ecotourism development in Batticaloa District of Sri Lanka using the GIS-based AHP spatial analysis. *GeoJournal of Tourism and Geosites, 46*(1), 252-261. https://doi.org/https://doi.org/10.30892/gtg.46128-1022

Popescu, V.D., Artelle, K.A., Pop, M.I., Manolache, S., & Rozylowicz, L. (2016). Assessing biological realism of wildlife population estimates in data-poor systems. *53*(4), 1248-1259. https://doi.org/https://doi.org/10.1111/1365-2664.12660

Rozylowicz, L., Nita, A., Manolache, S., Ciocanea, C.M., & Popescu, V.D. (2017). Recipe for success: A network prespective of partnership in nature conservation. *Journal of Nature Conservation, 38*, 21-29. https://doi.org/https://doi.org/10.1016/j.jnc.2017.05.005

Săgeată, R., Persu, M., Mitrică, B., Damian, N., & Mocanu, I. (2023). Shepherding at Mărginimea Sibiului (Romania); Past, Present and Future. *European Review, 31*(1), 65-89. https://doi.org/https://doi.org/10.1017/S1062798722000230

Velcea, I., Toderaș, T., Crăcea, T., & Negoescu, A. (2016). Pastoral transhumance in Mărginimea Sibiului. *Revue Roumanie de Geographie / Romanian Journal of Geography,* 60(1), 85-97. http://www.rjgeo.ro/issues/revue%20roumaine%2060_1/velcea%20et%20al.pdf

Yilmaz, O., Erturk, Y.E., Co Kun, F., & Ertugrul, M. (2015). Using livestock guardian dogs in Balkans. *Agriculture & Forestry, 61*(1), 161-173. https://doi.org/https://doi.org/10.17707/AgricultForest.61.1.21

Young, J., Draper, J.P., & Kinka, D. (2019). Spatial associations of livestock guardian dogs and domestic sheep. *Human-Wildlife Interactions, 13*(1). https://doi.org/https://doi.org/10.26076/frv4-jx12

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