INSTITUTO POLITÉCNICO DE BRAGANÇA
Escola Superior Agrária

IAV "Institut Agronomique et Vétérinaire Hassan II"

# Sustainable Management of mountain areas with high environmental value by using GPS Technology and Geo-processing.

**Ouiam Fatiha BOUKHARTA**

*Dissertation submitted to Escola Superior Agrária de Bragança to obtain the Degree of Master in Management of Forest Resources and the Degree of Engineer in Ecology and Management of Forest Resources under the scope of the double diploma with Institut Agronomique et Vétérinaire Hassan II de Rabat*

Supervised by

**Prof. Marina Castro (PhD)**

**Prof. João Paulo Castro (PhD)**

**Prof. Mhammed Bouhaloua (PhD)**

**Prof. Kenza Ait El Kadi (PhD)**

**Bragança**

**July 2020**

« Education is the most powerful weapon which you can use to change the world”

Nelson Mandela

# *Acknowledgement*

I would like to express my deep gratitude to my advisor ***Ms. Marina Castro***, Professor Doctor at the Escola Superior Agrária and to my co-advisor ***Mr. Joao Paulo Castro***, Professor Doctor at the Escola Superior Agrária. Their continuous support, motivation and immense knowledge allowed me to learn several research concepts that helped me in my final thesis and which will open doors for me in the future. I also want to thank them for the trust they gave me to present my research project to the ***Minister of Science and Technology of Portugal and his staff***.

My most respectful thanks to my advisor, ***Mr. Mhammed Bouhaloua***, Doctor at the Institute of Agronomy and Veterinary Hassan II, my co-advisor ***Ms. Kenza Ait El Kadi***, Doctor at the Institute of Agronomy and Veterinary Hassan II for their following-up, contribution and participation in the realization of my master's thesis.

I express my sincere respect and gratitude to all the professors and staff of the ***Institute of Agronomy and Veterinary Hassan II***, more precisely to my professors in the Department of ***Ecology and Management of Natural Resources***. Their intensive training in all fields has enabled me to acquire a lot of knowledge and concepts, which have been useful to both my personal and professional life.

A special thanks to my professors of the ***Instituto Politechnico de Bragança*** for their training, encouragement and kindness. ***Mr. Paulo Cortez'*** door was always open when I needed advice or help.

I would like to thank the ***Institute of Agronomy and Veterinary Hassan II*** and the ***Instituto Politechnico de Braganca*** for this ***Erasmus+ mobility*** project, a special opportunity to discover new learning methods from a world-renowned institute. In this context, I would like to thank ***Mr Noureddine Chtaina***, coordinator of this mobility, for his continuous monitoring, advice and encouragement.

Finally, I express my deep gratitude to my beloved mother, ***Professor Ilham Chentoufi***, the founder of my success. Nothing in the world is worth the efforts made day and night for my education, my well-being and my success. I also thank my father, ***Mr. Abdellatif Boukharta*** for his presence and support during these years, and my only brother, ***Mr Mehdi Boukharta***, for his precious advices, encouragement and continuous help. I thank them all for their unfailing support and continuous encouragement throughout my years of study, and I pray to God to keep them safe for me.

## *Abstract*

The production of small ruminants in North-East Portugal is an extensive activity, mainly based on the exploitation of spontaneous resources, which is strongly conditioned by seasonality. The shepherd directs his herds on daily grazing routes through different types of resources called by San Miguel (2004) "Mosaic of different land uses within the same management unit".

Recent advances in Global Positioning System (GPS) technology have led to the development of GPS collars, allowing the monitoring of animal movements at 5-minute intervals.

This study is part of the Open2preserve project, which aims to promote and enhance biodiversity. In this project, three GPS collars are used to track and analyse the routes of sheep, led daily by the shepherd, and to determine usage preferences by season. The experimental period of this study lasted 6 months (from 6 December 2019 to 6 June 2020), the results obtained refer to both winter and spring seasons.

The data obtained from the GPS collars are integrated into a Geographic Information System (GIS) to evaluate the characteristics of animal behaviour and grazing use. At the same time, a land use map of the Bragança Region was produced to determine the main classes of use, so that the data could be superimposed to obtain monthly preferences of grazing.

The results obtained show that the duration of the grazing circuits carried out by the sheep varies significantly over the months. In addition, sheep show preferences in land use choices in the study area, where the Permanent Crops and Grazed Forest classes are the most used compared to the other classes. In addition, roots are strongly conditioned by seasonal variations in environmental conditions, and by the shepherd who guides the sheep daily all along the experiment.



**Keywords:** GPS Collars – Small ruminants – Land use classes' Map – Land use preferences – Grazing itineraries – Duration of grazing – Preferences of Grazing - GIS

# *Resumo*

A produção de pequenos ruminantes no nordeste de Portugal é uma actividade extensiva, baseada principalmente na exploração de recursos espontâneos, que é fortemente condicionada pela sazonalidade. O pastor dirige os seus rebanhos em rotas diárias de pastagem através de diferentes tipos de recursos chamados por San Miguel (2004) "Mosaico de diferentes usos do solo dentro da mesma unidade de gestão".

Os recentes avanços na tecnologia do Sistema de Posicionamento Global (GPS) levaram ao desenvolvimento de coleiras GPS, permitindo a monitorização dos movimentos dos animais a intervalos de 5 minutos.

Este estudo faz parte do projecto Open2preserve, que visa promover e melhorar a biodiversidade. Neste projecto, três colares GPS são utilizados para seguir e analisar as rotas das ovelhas, conduzidas diariamente pelo pastor, e para determinar as preferências de utilização por estação do ano. O período experimental deste estudo durou 6 meses (de 6 de Dezembro de 2019 a 6 de Junho de 2020), os resultados obtidos referem-se tanto à época de Inverno como à de Primavera.

Os dados obtidos das coleiras GPS são integrados num Sistema de Informação Geográfica (SIG) para avaliar as características de comportamento animal e utilização de pastoreio. Ao mesmo tempo, foi produzido um mapa de uso do solo da Região de Bragança para determinar as principais classes de uso, de modo a que os dados pudessem ser sobrepostos para obter preferências mensais de pastoreio.

Os resultados obtidos mostram que a duração dos circuitos de pastoreio efectuados pelas ovelhas varia significativamente ao longo dos meses. Além disso, as ovelhas mostram preferências nas escolhas de uso do solo na área de estudo, onde as classes de Cultura Permanente e Floresta de Pastagem são as mais utilizadas em comparação com as outras classes. Além disso, as raízes são fortemente condicionadas por variações sazonais das condições ambientais, e pelo pastor que guia as ovelhas diariamente ao longo de toda a experiência.



***Palavras-chave:*** Coleiras GPS - Pequenos ruminantes - Mapa das classes de uso do solo - Preferências de uso do solo - Itinerários de pastoreio - Duração do pastoreio - Preferências de pastoreio - GIS

## *Résumé*

La production de petits ruminants dans le nord-est du Portugal est une activité extensive, principalement basée sur l'exploitation de ressources spontanées, qui est fortement conditionnée par la saisonnalité. Le berger dirige ses troupeaux sur des itinéraires de pâturage quotidiens à travers différents types de ressources appelé par San Miguel (2004) "Mosaïque de différentes utilisations des terres au sein d'une même unité de gestion".

Les progrès récents dont bénéficie la technologie du système de positionnement global (GPS) ont permis la mise au point des colliers GPS, autorisant la surveillance des déplacements des animaux à des intervalles de 5 minutes.

La présente étude fait partie du projet Open2preserve qui a pour objectif de promouvoir et de renforcer la biodiversité, et qui, dans ce projet, consiste à l'utilisation de trois colliers GPS, afin de suivre et d'analyser les itinéraires des moutons, conduit quotidiennement par le berger, ainsi que de déterminer les préférences d'usage par saison. La durée d'expérimentation de cette étude a duré de 6 mois (du 6 Décembre 2019 jusqu'au 6 juin 2020), les résultats obtenus réfèrent alors aux deux saisons d'hiver et de printemps.

Les données obtenues des colliers GPS sont intégrées dans un système d'information géographique (GIS) pour évaluer les caractères du comportement animal et de l'utilisation du pâturage. En parallèle, une carte d'occupation du sol de la Région de Bragança a été réalisée pour déterminer les principales classes d'utilisation, pour pouvoir faire la superposition des données, qui permettra d'obtenir les préférences mensuelles de pâturage.

Les résultats obtenus montrent que la durée des circuits de pâturage effectués par les moutons varie significativement au fil des mois. En outre, les moutons montrent des préférences dans les choix d'utilisation des terres dans la zone d'étude, où les classes Cultures permanentes et Forêts pâturées sont les plus utilisées par rapport aux autres classes. En outre, les parcours sont fortement conditionnés par les variations saisonnières des conditions environnementales, et par le berger qui guide quotidiennement les moutons tout au long de l'expérience.



***Mots-clés :*** Colliers GPS - Petits ruminants - Carte des classes d'utilisation des terres - Préférences d'utilisation des terres - Itinéraires de pâturage - Durée de pâturage - Préférences de pâturage - SIG

## *Index*

***Figures***

***Tables***



***ANNEXES***

# 1. Introduction

Nowadays, mountain areas are undergoing intense changes in the use of land and landscape, and therefore, in the organization of the territory (Bernáldez G., 1991; Gómez-Sal et al., 1993; Agreil and Meuret, 2004). These changes are mainly due to the rural exodus and the common agricultural policy, which generate situations of difficult compatibility within activities in rural areas. In recent years, the traditional dynamics of animal husbandry and forestry have been affected and gradually transformed by new abandonments, resulting in the loss of functionality of the territory (Castro and Castro, 2003). The need to reconcile traditional livestock and forestry activities with new uses requires an in-depth knowledge of small ruminants, as well as the environmental and social factors that determine it. The herds of small ruminants have a key function in the ecological dynamics of the territory (Castro, 2004).

The history of agricultural activity can be understood as a creative modification of different types of ecosystems done by humans, by modifying their structure and functional characteristics in order to ensure a sustainable supply of resources. Traditional systems take care of their adaptation to the environment through the selection of successful operating guidelines and elimination of bad practices (Gómez Sal, 2000).

Since 1955, livestock populations have faced a decreasing evolution in Portugal (Torres-Manso et al. 2014). The abandonment of rural areas, particularly in mountainous regions, has led to an increase in shrub areas and a decrease in pastures and cultivated areas (Ganteaume et al. 2013). These changes, combined with an increase in extreme weather events, have contributed to the dramatic increase in forest fire in most European countries along the northern Mediterranean (Ruiz Mirazo, Martinez Fernandez and Vega-Garcia 2012).

This study is part of the Open2preserve project whose main objective is to promote and strengthen biodiversity, nature protection and ecological infrastructure through transnational cooperation between Portugal, France and Spain (Interreg SUDOE Program). Open2preserve aims to consolidate traditional practices of prescribed burning associated with the grazing of sheep and horses. We are therefore taking this opportunity to reduce the risk of fire in the SUDOE territories and to develop sustainable management in order to enhance the value of the activities and contribute to sustainable local development.

Thereby, this study aims to analyse the grazing circuits of sheep flock in Vimieiro Parish in the municipality of Mirandela, district of Bragança from December de 2019 to June de 2020. This analysis is focus on the duration of circuits, the seasonal variation of intensity of territory usage and in the relationship between crossed land uses and temperature variation. This study was carried out using GPS (Global Position System) collars. The thesis is organized comprising six chapters:

- An introduction, first part of the report that introduces the subject;
- An overview of the agroforestry, the silvopastoral systems as well as the animal monitoring methods;
- The presentation of the study area and description of the methods utilized;
- Presentation of the results obtained and their interpretation;
- Discussion of results
- Conclusions

# 2. Literature review

## 2.1 Mediterranean region and silvopastoral systems

The countries of the Mediterranean region are characterized by fluctuations in climatic variability and uncertain precipitation (Gómez-Sal, 2000). This variability results a diversity of landscapes and land use systems, with high complexity and sustainability (Castro, 2004).

In the Mediterranean mountain areas, the heterogenetic mosaic landscape has an important role in grazing systems (Miguel-Ayanz, 2006). Indeed, the presence of several patches forms a discontinuity which offers greater resistance to the spread of forest fires compared to large-scale continuous forest areas (Loehle, 2004), which can produce more productive, profitable and sustainable systems than specialized forestry or animal production on their own (Jose, 2009; Peri et al., 2016).

Silvopastoral systems in the Mediterranean region occupy a place of great importance that improves significantly local economic and social values by facilitating stock grazing and providing forage and enhanced welfare to small ruminants (Castro et al. 2000). Silvopastoral systems provide several benefits. For instance, trees provide an attractive place for animals to rest and refresh themselves in the shade; animals deposit their droppings under the canopy, which increase fertility (Grove and Rackham, 2001).

The establishment of silvopastoral systems, which combines grazing and silvicultural interventions, makes possible the best use of low productive areas preventing fires, species diversity and mobilize the renewable energy sources of grass and wood (Livestock Institute, 2016). On the other hand, agroforestry systems, particularly, the grazing behaviour can be used as a forest fire prevention technique, since they implement a fuel management network at different scales of landscape by reducing fire risks (Etienne, 1996). For instance, fire regulation assures benefits for human safety, health and economies (Pettorelli et al., 2017; Haines-Young and Potschin, 2018).

Papanastasis (2004), pointed out the importance of planting olive tree in this region, which represents the most important planted evergreen species forming agro-silvopastoral systems in the Mediterranean region, which can be used for both production of olives for man and foliage for animal feed. Other trees, for example *Quercus* species have a direct value as a fodder crop, providing acorns in autumn and leaves in summer (Castro, 2009).

Many efforts have been made to classify silvopastoral systems (Nair, 1993; Etienne, 1996; quoted by Miguel-Ayanz, 2004). The basic classification of Etienne, in 1996, which takes into account the distribution of the woody and herbaceous vegetation and animals, and have elaborated a classification of Mediterranean European silvopastoral systems is:

- Grazing and browsing in shrublands or forests: a type of natural shrublands, that includes Maquis, Garrigue, etc., and where coppices and high forests are the most widespread systems in Portugal.
- Scattered trees on swards: a type of wild trees, which is represented by Dehesas (land dedicated to grazing cattle) and Montados of cork or holm oak (*Quercus suber* and *Quercus ilex*).
- Mosaic of different land uses within one management unit: this type is one of the most representative systems in mountainous areas in the Mediterranean Region and the North of the country and it is the system studied in our thesis.
- Scattered trees on swards: a type of plantations in Mediterranean areas that are described by the presence of agricultural trees like olives and almonds (in the mountain areas of the North).

## 2.2 Extensive livestock systems

The extensive livestock system is an activity based on the interaction between Human, herd and territory (Balent and Landais, 1995), which depends mainly on the spatial and temporal diversity of the region, as well as the availability and heterogeneity of forage resources (Balent, 1987). The extensive livestock usually have a low stocking rate and is essentially based on the natural resources, where the shepherds directs their flocks on itineraries across different land cover patches (Barbosa and Portela 2000; Castro et al. 2010). Generally, this activity has a particular role in vegetation dynamics (Palmer and Hester, 2000). This kind of system is characterized by the breading of animals with economic interest, able to profit of natural resources, with low implementation of advanced technologies (Bellido et al., 2001). Diets based on low-energy forages in this system promotes muscle’s growth without excess fattening (Lawrie, 1998). Indeed, lambs from production systems have higher energy requirements due to the increase of the basal metabolic rate (forage diet) and the increased of the physical activity (grazing), resulting in the production of lighter and leaner carcasses (Murphy et al., 1994; Diaz et al., 2002).

In the other hand, extensive livestock can be used too as an instrument to reduce wildfire hazards (Fernandes et al. 2013, Fernandes et al., 2016). In the Mediterranean Region, the extensive livestock systems have shaped a mosaic landscape, dominated by heterogeneous plant communities, comprised by forests, shrubs, herbaceous communities, which give resilient ecosystems with a high species diversity, productivity and utility to society (Kizos et al, 2013).

In Trás-os-Montes region, small ruminant production is an extensive activity based on daily movements of livestock around their villages, where the shepherds use several daily itineraries of the spontaneous vegetation that are influenced by the environmental conditions, because animals are very sensitive to extremes of temperature and availability of resources (Castro, 2015). The land use management, the rules where animals can cross and graze in the grazing circuit and their adaptation to environmental conditions are based on long-established indigenous knowledge and practices (Barbosa and Portela, 2000).

## 2.3 Animals and Ecosystem services

Ecosystem services are the direct and/or indirect benefits that humans derive from ecosystems, which contribute to make human's life possible and worth living (Daily, 1997; Braat et al. 2018). Mountain areas provide many services, such as water supply, climate regulation, support for biodiversity (both wild and cultivated), contribution to cultural heritage and support for tourism and recreation (Thuiller et al 2005). In Portugal, mountains account for more than 39% of the surface area, of which 26% of its services are provided to the population, reflecting the major importance of the presence of ecosystems in the country (Aguiar et al 2009; Lomba et al 2013; Carvalho-Santos, Sousa-Silva, et al 2016).

The presence of animals in grazing areas is therefore an essential tool for maintaining and rehabilitating animal and environmental biodiversity, hence the need to identify and apply good grazing practices in order to best manage the environment and preserve the biodiversity present in the ecosystem (Müller, 2015).

The trampling of animals will allow the creation of micro-topographic forms, which will increase the diversification of the environment and thus the biodiversity present; this will limit competitive species and lead to the expression of numerous groups of plants (Majchrzak, 1992; Cholet and Magnon, 2010).

## 2.4 Monitoring grazing animals

The patterns of land use by free-ranging animals are a central element in the management of pastoral ecosystems (Castro, 2004). A central issue in grazing studies is to understand how vegetation structure and composition influence the rate at which animals ingest plant material and thereby nutrients (Bonnet et al., 2015). However, measuring grazing by herbivores, and how local differences in vegetation structure and composition affect this rate, has long been a major methodological issue because of the difficulty to obtain reliable estimates of individual bite mass (Gordon, 1995; Mayes and Dove, 2000).

While grazing, animals play an important role in forest fertilization (Gómez-Sal, 2000) and controlling combustibles (Etienne et al., 1994; Castro, 2008; Mosquera-Losada et al., 2006;). Animals benefit from the welfare and food supply provided by the woody component (Castro et al., 2004). Biodiversity and landscape conservation is currently also a central element in the enhancement of agroforestry systems, which is improved through animal grazing (Eichhorn et al., 2006).

The technology to track animals has started in the 1960s and 1970s (Craighead et al., 1972), and was expanded with the development of the ARGOS satellite system in the 1980s, which is an alternative method of mapping long-distance movements of migrating animals based on ultra-high frequency (Rodgers 2001; Bradshaw, Sims and Hays 2007).

Monitoring animal behaviour in correlation with environmental information can improve land management (Ganskopp et al., 2000; Turner et al., 2000). However, monitoring simultaneously records animal movement and behaviour that is highly dependent on the landscape (Hulbert and French, 2001). It is an assessment process used by animal and natural resource managers to assist and determine how rangelands or grazing systems respond to the ecosystem (Holechek et al. 2004).

## 2.5 Methods to monitor grazing animals

Gordon (1995) pointed that: "There is no best technique for making measurement. The most appropriate technique will depend upon the goals of the research and the circumstances under which the measurements are made including such considerations as the time scale of the study, grain of heterogeneity, the availability of tame animals, logistics and funding".

Grazing ecologists have developed a series of techniques to measure the components of the foraging strategy (Gordon, 1995). Scientists are now using new technologies as Global Positioning System (GPS) data to track and monitor the behavioural ecology of free-ranging animals (Ungar et al., 2005; Tomkins and O'Reagain, 2007), which may allow them to detect subtle changes in livestock behaviour (Barwick, 2017).

## Direct observation

Traditionally, information on the location of animals was gathered by direct observation (Attwood and Hunter, 1957; Arnold, 1984/1985; quoted by Gordon, 1995). This method has been used to assess the feeding habits and diet composition of free-ranging herbivores for more than 80 years (Dixon 1934; Doran 1943). The technique was adapted to give estimates of diet composition, daily intake and detailed information on the process of diet selection itself all along the grazing journey (Meuret, 1989). Following and observing animals successfully accomplish ecology and behaviour studies directly, which allows for everything that can be observed or heard to be recorded in real time (Scheibe et al. 2008).

The direct observation method can be combined with using markers are among the most preferred techniques to assess diet composition and intake, because they reflect animal choices and mimic what animals really ingest (Gordon 1995; Mayes and Dove 2000). A marker is a distinctive inert chemical signature that allows the recognition of its presence in a mixture (Oliveira et al., 2013).

However, the direct observation monitoring may arise some problems and limitations. For instance, this method is very time-consuming and requires the utilization of relatively tame animals in order to observe the grazing behaviour (Gordon, 1995). Problems include also the fatigue of the observer, physical limitations, external factors (weather and light), and the effect of observer proximity on animal behaviour (Turner et al., 2000). There are also risks of injury and transmission of diseases for both observer and subject (Williamson & Feistner 2003, Doran-Sheehy et al. 2007). Although it is predicted that at the end of the process the observer will be totally accepted by the animal, the observer will not always be a neutral element (Jack et al. 2008).

## Precision farming by using time-lapse Cameras

Precision farming using cameras is the result of the development of new technologies in the nineties and today appears to be a tool that can meet the economic, social and environmental challenges of animal husbandry (Allain et al, 2014). Cameras and sensors can provide a 3D image and automated measurements of the animal in order to assess its body condition and its movement, by sending notifications to breeders in the event of too great a variation in fattening status for example, allowing them to detect problems of under-nutrition and intervene quickly to treat the animal (Delaval, 2017).

Several projects have correlated recorded vocalizations of the movement of free-ranging animals with the level of animal welfare (Moi et al, 2015; Meen et al, 2015). Thus, thanks to these recordings, the farmer can detect an animal's malaise and can observe it more closely, in order to potentially detect the factors causing this malaise, since sound analysis is very useful in detecting a deterioration in the animal's well-being (Hoffmann, 2018).

## Ear tag–based accelerometer system for detecting grazing behaviour

Visual observation is the most common method to validate precision dairy technologies, but it can be laborious and bias may exist between observers (Borchers et al., 2016). The ear tag has been validated in confinement herds for rumination time and showed a strong association compared with visual observation (Borchers et al., 2016) and video recording (Reiter et al., 2018). In a grazing dairy herd, the ear tag was used to evaluate behaviours of cows on pasture and showed high correlations for eating and rumination behaviour compared with visual observation (Pereira et al., 2018).

Using the ear tag–based accelerometer system to identify makes the identification easier to find out, good legible, durable, fixed against the loss and safe when identifying the animal, and has to be resistant against the loss of the legibility and not reusable (Caja et al. 2004). Grazing is a difficult behaviour to define because animals can walk and stand to graze or walk continuously and pick bites of grass from the pasture, while simultaneously ingesting forage (Werner et al., 2018). An ear tag is then a system used to monitor individual animals from ear and head movements and positioning, to detect grazing behaviour on pasture-based dairy farms (Pereira, 2020).

## Very-high frequency VHF Radio Signal Tracking

Very high frequency technology (battery-powered transmitter, receiver, and recorder) has been commercially available since the late 1950s (Rodgers et al. 1996). These modern transmitters are small and versatile, which allow the tracking of many small animals like mice, birds and ghost crabs (Mech, 1983). Nevertheless, this technology is by far the most useful and versatile type of radio tracking, for not only does it yield location data, but it also allows investigators to gather a variety of other types of information (Mech, 1983). Location and accuracy cues depend on terrain, visibility, discomfort and fatigue (Gibb et al., 1998). For example, VHF radio signal tracking is a radio emitter attached to the animal of interest and generates a unique signal to identify, remotely locate and observe the animal (Turner, 2000).

The advantages of VHF tracking are relatively low cost, reasonable accuracy for most purposes, and long life; disadvantages are that it is labor-intensive and can be weather-dependent (Mech, 2002). In fact, an obscured view of the sky by trees or mountains may limit the functionality of satellite-based systems (Lewis, 2007).

## Global Positioning System (GPS) for Animal Monitoring

Almost all of the proposed tools to improve livestock grazing distribution are realized over 60 years ago (Williams; 1954). However, the ability to test and refine these techniques were limited due to the difficulties and labour required to observe visually the livestock grazing patterns, which represents one of the major principles of grazing management (Vallentine, 2001).

About 20 years ago, GPS collars became commercially available and started to be employed in research on livestock grazing (Turner et al., 2000; Swain et al., 2011). The use of GPS technology in the study of animal movement has opened up a whole world of possibilities and it is an area of research that is progressing rapidly (Morales et al. 2004; McClintock et al. 2012). This new technology, which gives the possibility to track and monitor livestock on a 24-hour basis for weeks and months, has facilitated major advances in livestock behaviour and grazing management research and has significantly increased the amount of studies evaluating practices distribution and spatial movement patterns of livestock (Bailey et al., 2018)

GPS technology is a tool that allows the location of animals and their movements, as well as environmental variables, making it possible to calculate the distances covered, the speed and behaviour, among other aspects of their daily activity (Castro and Castro; 2009). The GPS collar adopt several perspectives:

- Monitor and observe grazing itineraries (Buerkert and Schlecht, 2009);
- Determinate the behavioural states of grazing livestock from high–frequency position data alone (Homburger et al, 2014);

- Moreover, the evaluation of spatio–temporal differences in grazing patterns and land use preferences of livestock through GPS trajectories analysis (Feldt and Schlecht, 2016).

The advent of GPS tracking allowed researchers to accurately monitor livestock grazing patterns for weeks to months and validate the effectiveness of techniques designed to improve distribution (Bailey et al., 2018).

GPS precision and accuracy have essentially overcome many of the problems of bias and precision posed by VHF technology (Tomkiewicz et al. 2010). The GPS tracking provides data employed to develop grazing distribution traits, and the geographical information system software (GIS) calculates the average slope and elevation use of tracked animals (Bailey et al., 2018).

The GPS collars, combined with the digital elevation maps and geographical information systems (GISs) is employed to quantify the time spent in an area by animals, which is used as an indicator of area occupation by the quantification of terrain use of livestock on rangelands (Bailey, 2018).

## Precision Livestock Farming

According to Berckmans (2006), in English « Precision livestock farming is a concept that covers the use of modern technology based on sensors, detection systems (images, sounds, etc.), real-time modelling and software to carry out continuous automatic monitoring and management on farms. Its technology is based on recent advances in information and communication technologies (ICTs) and their sensors, combined with mathematical and biological models. In the animal domain, information is collected at the level of the building, the farm, the region, the country and Europe. »

For the farmer, precision grazing proposes to identify and control the variability of "grazing pressures" within paddocks, as well as to systematically weigh each animal by electronically identifying it as it passes through a corridor to a distribution point (Meuret et al., 2013). Indeed, the equipment necessary or envisaged for herd control includes collars equipped with GPS, with UHF (Ultra High Frequency) or Wi-Fi satellite transmission, for the animals, without neglecting the hygrometry and the sensitivity of the ground to trampling, which will be compiled on a topographical background and processed by the GIS geographic information system (Meuret et al., 2013).

# 3. Material and methods

## 3.1 Study area

### Location of the study area

The experiment was conduct in the Northeast of Portugal in the parish of Vimieiro (41°32'14.80" and 7°3'36.18", 495-530 m MSL), in the municipality of Mirandela, district of Bragança (Figure 1). The study area is included in the Site of Community Importance – Romeu (PTCON 0043).

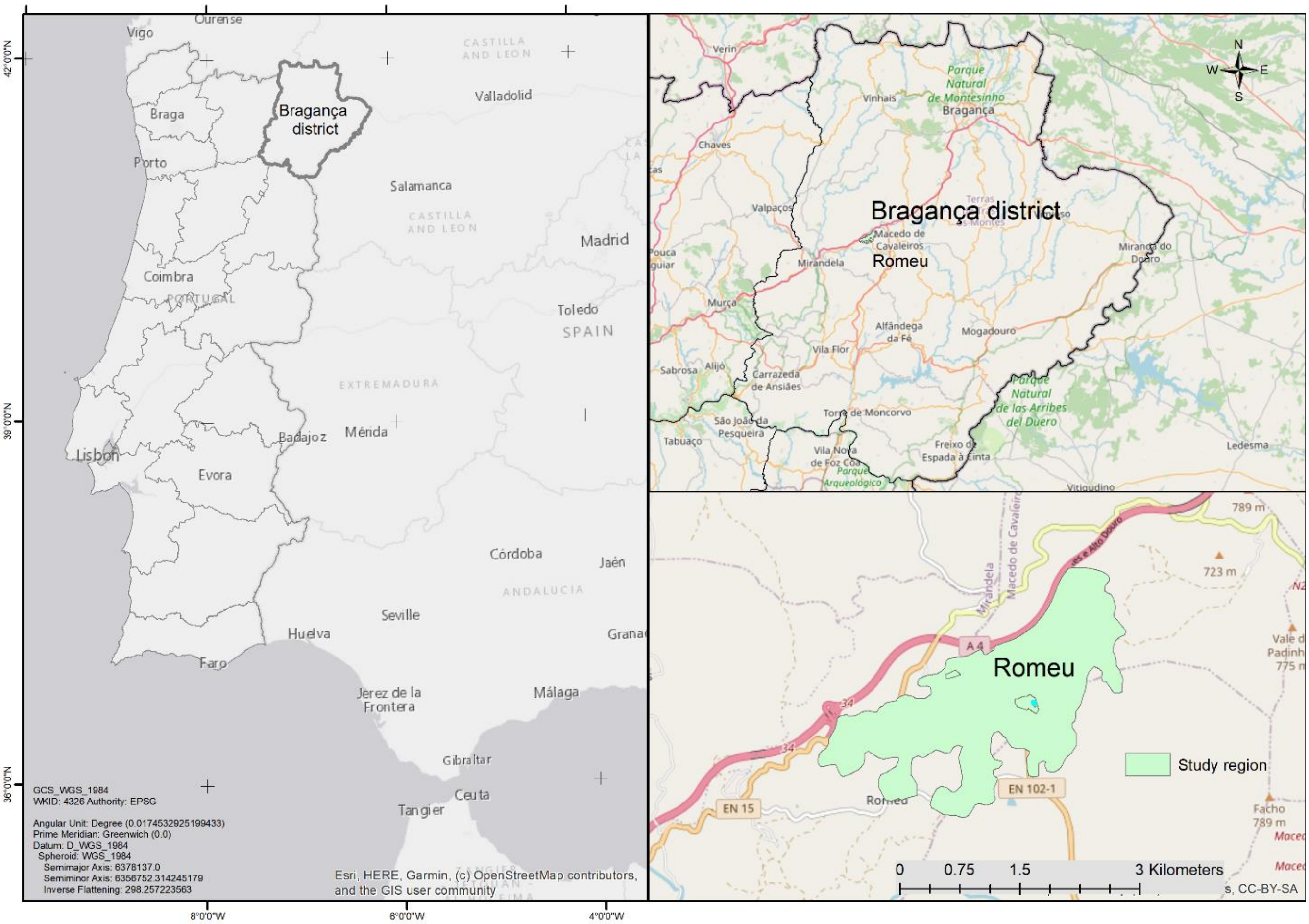



Figure 1: Location of the study area, Vimieiro

### Climate conditions

Due to the lack of climatic data from Vimieiro, we present data for the last thirty years of precipitation and temperature of Mirandela (Figure 2), the nearest synoptic station, obtained from the National Institute of Meteorology and Geophysics (INMG) of Portugal; with a latitude of 41° 31N, a longitude 7° 12' W and an elevation of 250 m MSL.

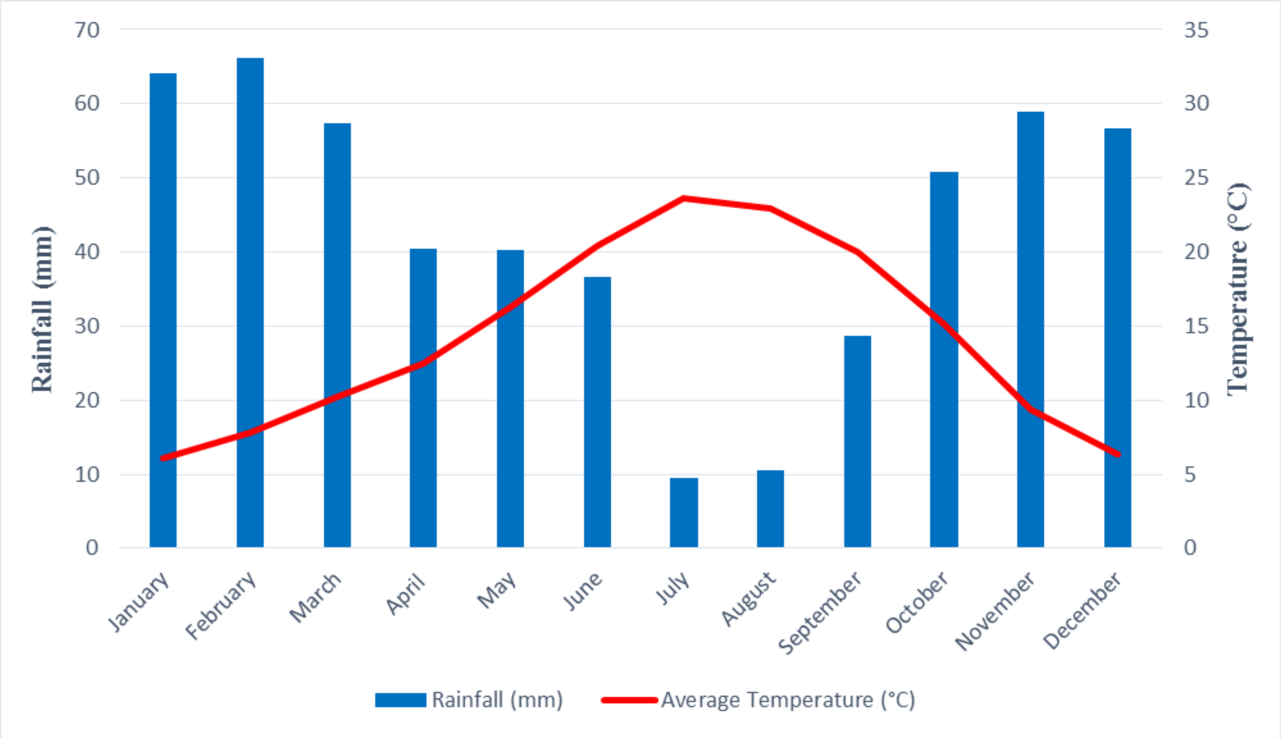



Figure 2: Ombrothermal diagram of Mirandela (1951-1980, INMG, 1991)

The mean annual temperature is 14.2°C, the minimum and the maximum temperature of the coldest monthly is 2°C and 10.2°C; and the minimum and the maximum temperature of the hottest month is 15.6°C and 31.6°C. The annual rainfall is 520.1 mm (INMG, 1991, period 1951-1980). According the Rivas Martinez classification (1983), the region has a dry (300-600 mm) Meso-Mediterranean climate.

## Native and agroforest vegetation

Cork oak forests prevail in the SIC landscape (habitat 9330 - *Quercus suber*) with some *Juniperus oxycedrus* (9560 - endemic forests of *Juniperus* spp.) in their lower sector. Holm oak (*Quercus ilex* and *Quercus rotundifolia* - 9340) and *Quercus faginea* are also relevant in the area of implementation of the experiment. The associate understory is relatively dense (30-60%) sometimes associated with some shrubby cover: *Cytisus scoparius* and *Cytisus multiflorus*, or *Cistus ladanifer* and *Lavandula stoechas*, depending on micro ecological conditions. The presence of *Crataegus monogyna* and *Prunus spinosa* in the wetter areas associated with *Q. faginea* is also frequent (Onaindia et al. 2004).

Concerning the land use, in Romeu, the landscape is an uneven set of different classes, mainly annual and perennial crops, pastures, woods, shrubs and forests (Castro et al., 2016).

## Herd

The flock of sheep monitored is the breed of “Churra Galega Bragançana” and is comprised by 165 females and 3 males for meat production. This breed is included in the group of those supported by the Regional Development Plan (EAFRD, Decree-Law No 137/2014 of 12 September). Currently, in Bragança Region, the breed has 16,163 animals registered in the herd book, distributed among 169 breeders. The feeding of the herd is based on grazing circuits along which the it selects different forage resources.

## Pictures of the study area

Figure 3: Churra Galega Bragançana in the study area (photo by author)

Figure 4: Study area (photo by author)

## 3.2 Land Use Classes (LUC)

The creation of a LUC map is necessary to determine the different land uses, and therefore, to identify the daily preferences of each sheep. Indeed, this is done by superimposing the data collected from the movements of the sheep wearing the GPS collars and the vegetation map itself, and to evaluate the relevance of climatic conditions in the choice of the shepherd for the occupation of the soil to be grazed.

The vegetation map of the Region of Bragança was obtained from COS2018 (Carta de Uso e Ocupação do Solo de Portugal Continental), from the DGT' website (Direção-Geral do Território), and which represents a thematic cartography that aims to characterize in detail the occupation and use of land in the territory of mainland Portugal. This mapping was carried out from the visual interpretation of orthorectified aerial images, with high spatial resolution. The information is in vector format and has a minimum cartographic unit of 1 hectare and a minimum distance between the lines of 20 meters.

The production of the COS2018 is a strategy that provides information on land use and occupation with regularity and reliability through more efficient and technologically more advanced production processes, where information produced are made available to the public through the website http://www.dgterritorio.pt/dados_abertos/cos/. This work allows the analysis of land use and occupation dynamics for mainland Portugal.

The COS nomenclature (Annex 2) was reformulated for the production of COS2018 within the scope of a working group of the National Territory Commission (CNT) coordinated by DGT and which brought together relevant entities in the fields of land use and occupation.

In order to analyse the use of the territory by the flock, the COS2018 land use and cover classes were grouped into eight main classes (Table 1): annual crops (AC); Prairie (G); Grazed forest (GF); Permanent Crops (PC); Shrubs (S); Urban area (U); Ungrazed forest (UF) and water (W).

Table 1: Land use classes (LUC) of Bragança Region - Source: Castro et al., 2020

| *Class name* | *Descriptions* |
|---|---|
| Annual crops (AC) | Arable land, worked regularly, usually on a crop rotation system. Land cover with bare ground in July after crop harvest. |
| Permanent Crops (PC) | Consist mainly of vineyards, olive groves, chestnut and almond orchards. Land cover with a rough texture and with a repetitive pattern. |
| Grasslands (G) | Permanent pasture of herbaceous plants seeded or with the natural origin for cattle grazing or cutting hay or silage. Coverage of soil with fine texture and slightly dark and homogeneous shade. |
| Shrublands (S) | Areas with shrubs and low grown trees as well as sparsely tree-covered areas. Land cover with coarse and irregular texture with a medium dark tone. |
| Grazed Forests (GF) and Ungrazed Forests (UF) | Forest is LUC classes with tree crown cover of more than 10 percent. Hardwoods exhibit higher overall reflectance than conifers. Forest areas, in general, have a coarse texture. In mixed forests, the texture is very coarse and irregular. Forest are divided in two classes, grazed and ungrazed forest. |
| Urban (U) | Artificial surfaces intended for activities related to human societies. The appearance of urban areas in images may vary widely, depending on whether they are predominantly horizontal or vertical, continuous or discontinuous. |
| Water bodies (W) | Rivers; reservoirs and lakes. Dark tone due to reduced overall reflectance. |

## 3.3 Data collection

GPS collars (proven monitoring technology) were used to track the movement of animals throughout the day in the Romeu region, where the experiment was carried out.

A vegetation map, containing the different classes of uses, was obtained from COS2018 of the Bragança Region, as explained in the point 3.2 The dispersion of animal location points, obtained from GPS collars, was superimposed on the vegetation map produced, in order to limit our study area and then to identify the sheep's preferences.

The movement of the animals throughout the day, month and year depends on the climatic conditions. This allows the shepherd to aim and evaluate its relevance in the choice of routes for the occupation of the land to be grazed. The climatic data were obtained from the ESAB automatic station, with the help of Mr Nuno

The use of software such as QGIS and SYSTAT in this study are necessary to obtain information that would allow us to analyse, interpret statistically, and thus identify the desired preferences, which is the main objective of this thesis topic.

The monitoring of sheep by GPS collars in this experiment lasted six months, from December 6, 2019 to June 6, 2020. The study is based on the calculation of the time spent by the sheep in each land use of the territory, and the routes taken during this period, noticing that the shepherd always guides sheep.

## Herd monitoring equipment

### *GPS collars*

The DOMODIS GPS system allows us to locate animals every 5 minutes, in almost real time, and to assess their movement over discriminated periods. This permits to calculate distances crossed, time in each land use, time of grazing circuit, etc. The GPS collars were purchased in the fall and they were available to start the monitoring process on 21 November 2019. Each device includes a hermetically sealed box that houses the battery (not charged), the GPS receiver, and other electronic equipment for data transmission. The collars are made of material capable of resisting environmental adversities, easy to mount on the animal's neck.

Figure 5: GPS Collar (DOMODIS) (photos of the author)

## System Activation

### *Recharging the battery*

The system was delivered without charge. It is necessary to fully charge before usage. Therefore, the same day, we putted the batteries in charge and this for 24 hours.

The battery should always be charged with the supplied charger. For this, we inserted the male connector of the charger with the female connector of the battery pack. After 24 hours, the light of the LED changed from red to green light (Figure 6). This operation should be done every 3 months.

For safety reasons and because of the use of high capacity batteries, we have ensured the batteries that are in charge in a safe place, without any element likely to catch fire in case of explosion of the battery.


Figure 6: Recharging the batteries and turning from red to green light.

### *Description of LEDs and their meanings*

When the system is connected for the first time or the power button is pressed, the GPS LEDs warns if it is possible to see the GPS satellites and get a GPS position:

GREEN Led: The GPS LED flashes green for 20 minutes if the device can see the GPS satellites and search / found a GPS position.

RED Led: The GPS indicator flashes red for a short time if the unit does not see the GPS satellites and cannot find a GPS position. If the GPS LED is blinking red, you need to move your system or another location with a clear view of the sky.

Both lights will stop blinking after 20 minutes to save power, but the unit will continue to be connected and will send the GPS position.

### *Installation and commissioning of the system*

The screws of the GREY cover must be loosened with a screwdriver of the appropriate size to prevent damage. The direction of rotation of the screwdriver must be counter clockwise (Figure 7).


Figure 7: Collar's cover (contains the battery) (photos of the author)

Disconnect the batteries already present in the lid and insert the previously charged ones by plugging in the two connectors (on the cover and the battery module) (Figure 8)

Figure 8: Connect the charged batteries and plugging of the two connectors (photos of the author)

***First activation of the GPS collars***

Step 1: It is very important to activate the system in a bright outside area so that the system starts correctly and can acquire the GPS signal (Figure 9).

Once the battery is connected, press the "on-off" button for 3 seconds. The "LED on" and "GPS LED" lights flash. Blinking means motion detection.

Figure 9: Activation of the batteries in an open area to test if the dispositive are working in a good way (photos of the author)

Step 2: When the system is correctly activated, we have screwed the top cover making sure that the connector is placed in the hole indicated on the picture so as not to damage the connection.

Step 3: Tighten the screw enough so that the seal perfectly closes the lid at the base (Figure 10).


Figure 10: Battery screwed, which contains the battery, charged

To turn off: Press the power button for 3 seconds. When you press the button, the unit switches from GPS mode to disabled mode.

It is essential to change the battery when the device is turned off. To do this, before disconnecting the battery, you must press the on / off button for 3 seconds until you remain active (no light indication). Once you have confirmed that it will not turn on, it will never be time to disconnect the battery. If this process is not followed, the unit may be blocked and out of warranty.

When the device is active, most of the time, the lights off, it means that he is asleep. You should not interpret the device until it is turned off; the only way to confirm this is to briefly press the power button. If one of the LEDs begins to indicate that it will indicate that, the device is active.

Result: The first result obtained while experimenting the GPS batteries for the first time outside the building of the “Escola Superior de Agrária” is presented in the Figure 11.


Figure 11: First result obtained from the GPS's location

Therefore, the collars are working in a good way. The next step would be to assemble and attach the collar to the sheep.

***Mounting and fixing the collar***

All breeding systems are supplied with the appropriate clamp for each type of animal. To install it, the first step was to remove the two fixing nuts with a suitable seal: First, remove the self-locking nut, then the single nut or the washer. Just release one of the two fasteners to access the housing.

The electronic box should be placed in the appropriate position, as shown in the picture, and close the Velcro.

After receiving the collars and charging the batteries, we went to the study area to insert the collars on the sheep. That was on the 5 December 2019. From that day, the movement of sheep has been done by following their trajectories during the whole day from the 6th of December to the 6th of June.

*Important:*

1- The cover of the control unit (part where the 4 screws are located) must always be turned outwards, never towards the side of the animal. This is essential for optimal coverage of the GPS and GSM system.

2- Secure the housing to the collar by mounting and tightening the self-locking nut, washer nut and washer assembly. The head of the screw must always be perfectly locked so as not to damage the animal.

3- Attach the collar to the animal so that it is locked on the side of the neck (
Figure 12).

Figure 12: GPS Collar fixed in the good way (Photos of the author)

### ***DOMODIS website***

The DOMODIS website gives all information relating to each sheep. After entering the username and the password, the main page shows the last movements obtained for each animal, including the date, the exact last location (longitude and latitude) and the state of the battery's charge (Low or Good) (Figure 13).


Figure 13: DOMODIS's User Interface (http://www.loc.gpsganado.es/index.php)

The icon to the left of the location allows us to choose:

- Which device we wish to pursue (Marina1, Marina 2 or Marina 3),
- The start and end dates of the days we want to study and;
- The number of positions we want to obtain (number: between 1 and 999). For more precision, we always choose 999 points, to have more reliable results and which reflect on reality (example presented in the Figure 14).

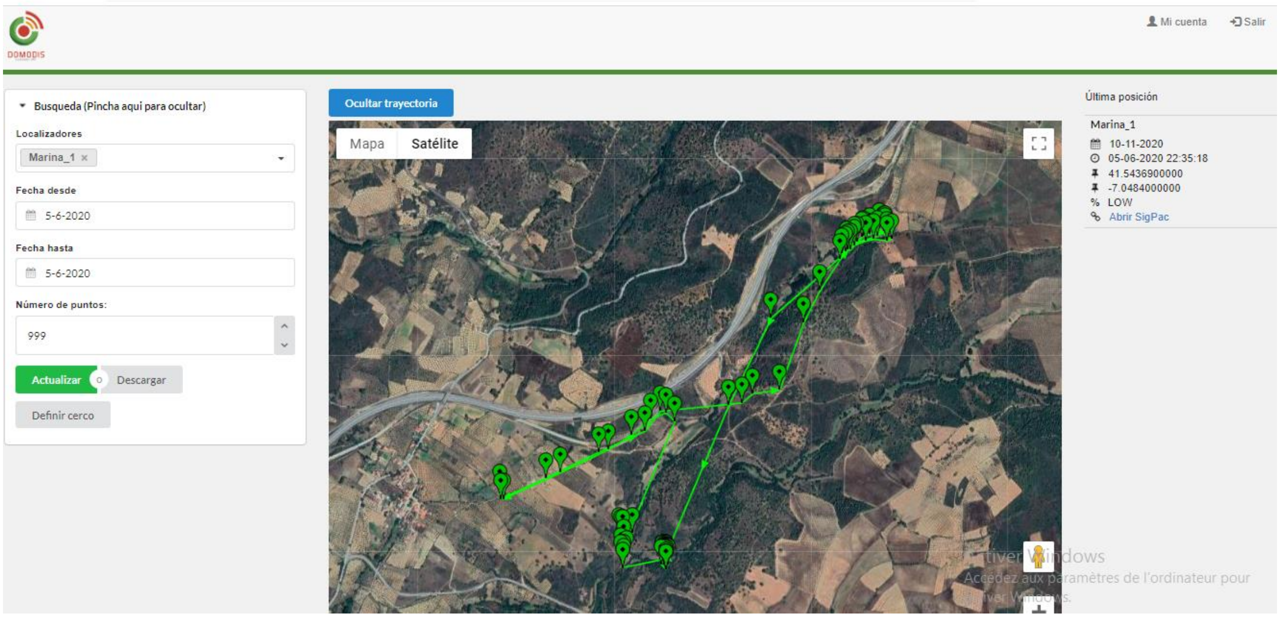


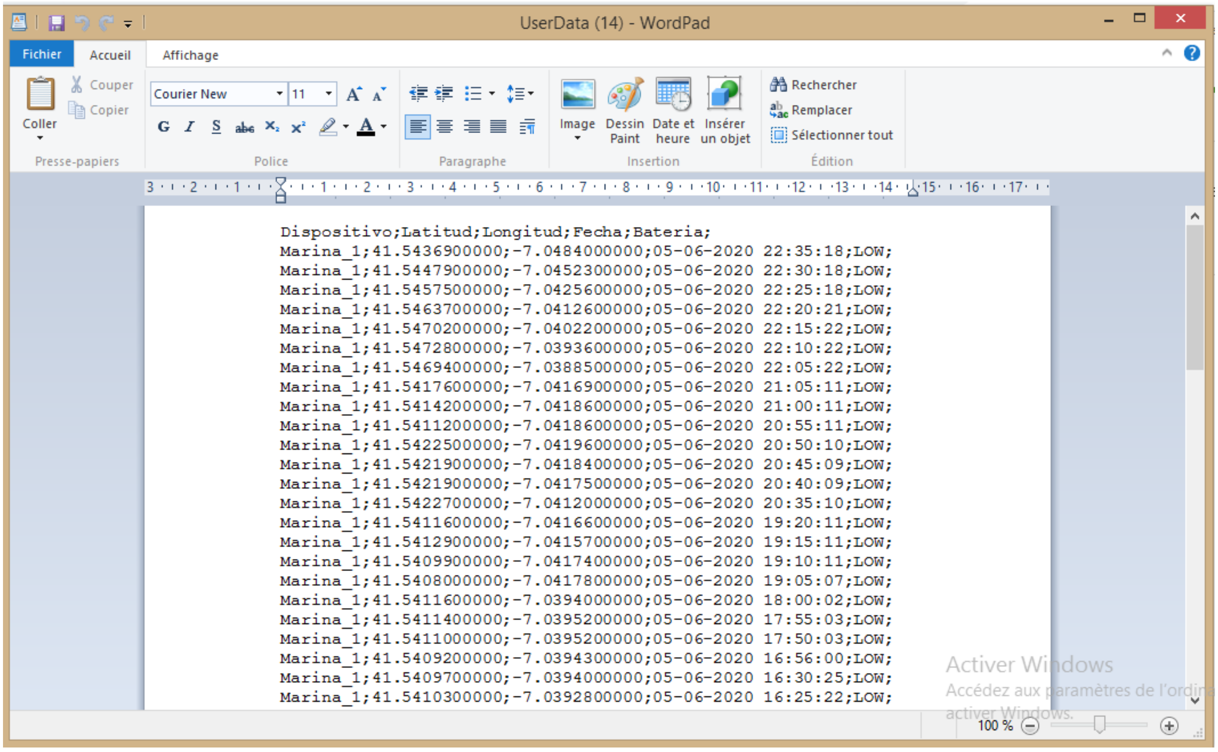
Figure 14: Example of a location for a specific date (05-06-2020)

### Importing Data

Sheep movement data are downloaded in txt format from the DOMODIS site (Figure 15), these data are copied into an excel file, while converting the text into columns, which is updated daily after each addition of data (Annex 1). After saving all the information, the file is imported from the Excel form (in csv) to the QGIS software for interpretation. The QGIS software project is already formatted to open the csv file and convert it to points in the CRS WGS84.

After recording all the grazing movements obtained during these 6 months of experience, their projection on the QGIS software allowed us to predict the exact study area. The next step is therefore to limit manually this area via QGIS, while overlapping with the vegetation map already made of Bragança, in order to identify our region of interest (ROI) which will be used in the following steps.

It is necessary to create a ROI, consisting on a polygon, which contains all the points recorded during the 6 months of sheep tracking.



```
Dispositivo;Latitud;Longitud;Fecha;Bateria;
Marina_1;41.5436900000;-7.0484000000;05-06-2020 22:35:18;LOW;
Marina_1;41.5447900000;-7.0452300000;05-06-2020 22:30:18;LOW;
Marina_1;41.5457500000;-7.0425600000;05-06-2020 22:25:18;LOW;
Marina_1;41.5463700000;-7.0412600000;05-06-2020 22:20:21;LOW;
Marina_1;41.5470200000;-7.0402200000;05-06-2020 22:15:22;LOW;
Marina_1;41.5472800000;-7.0393600000;05-06-2020 22:10:22;LOW;
Marina_1;41.5469400000;-7.0388500000;05-06-2020 22:05:22;LOW;
Marina_1;41.5417600000;-7.0416900000;05-06-2020 21:05:11;LOW;
Marina_1;41.5414200000;-7.0418600000;05-06-2020 21:00:11;LOW;
Marina_1;41.5411200000;-7.0418600000;05-06-2020 20:55:11;LOW;
Marina_1;41.5422500000;-7.0419600000;05-06-2020 20:50:10;LOW;
Marina_1;41.5421900000;-7.0418400000;05-06-2020 20:45:09;LOW;
Marina_1;41.5421900000;-7.0417500000;05-06-2020 20:40:09;LOW;
Marina_1;41.5422700000;-7.0412000000;05-06-2020 20:35:10;LOW;
Marina_1;41.5411600000;-7.0416600000;05-06-2020 19:20:11;LOW;
Marina_1;41.5412900000;-7.0415700000;05-06-2020 19:15:11;LOW;
Marina_1;41.5409900000;-7.0417400000;05-06-2020 19:10:11;LOW;
Marina_1;41.5408000000;-7.0417800000;05-06-2020 19:05:07;LOW;
Marina_1;41.5411600000;-7.0394000000;05-06-2020 18:00:02;LOW;
Marina_1;41.5411400000;-7.0395200000;05-06-2020 17:55:03;LOW;
Marina_1;41.5411000000;-7.0395200000;05-06-2020 17:50:03;LOW;
Marina_1;41.5409200000;-7.0394300000;05-06-2020 16:56:00;LOW;
Marina_1;41.5409700000;-7.0394000000;05-06-2020 16:30:25;LOW;
Marina_1;41.5410300000;-7.0392800000;05-06-2020 16:25:22;LOW;
```

Figure 15: Data obtained from the DOMODIS site in txt format

Since the GPS collars record the position of the sheep every 5 minutes, and since our objective is to identify only the selective grazing behaviour, it is necessary to remove the points where the sheep are in the sheepfold in order to obtain effective grazing only, which would inform us about the preferences of sheep during grazing.

The ROI was therefore designed to have only valid points of grazing behaviour. For instance, we can also create a stable exclusion mask, making holes to eliminate points where the animals spend the night (Figure 17).

The selection of points by location is done in the shapefile "Parcours extend.shp" and its export is done to ShapeFile parcours.shp while transforming into CRS ETRS89 (Figure 16).

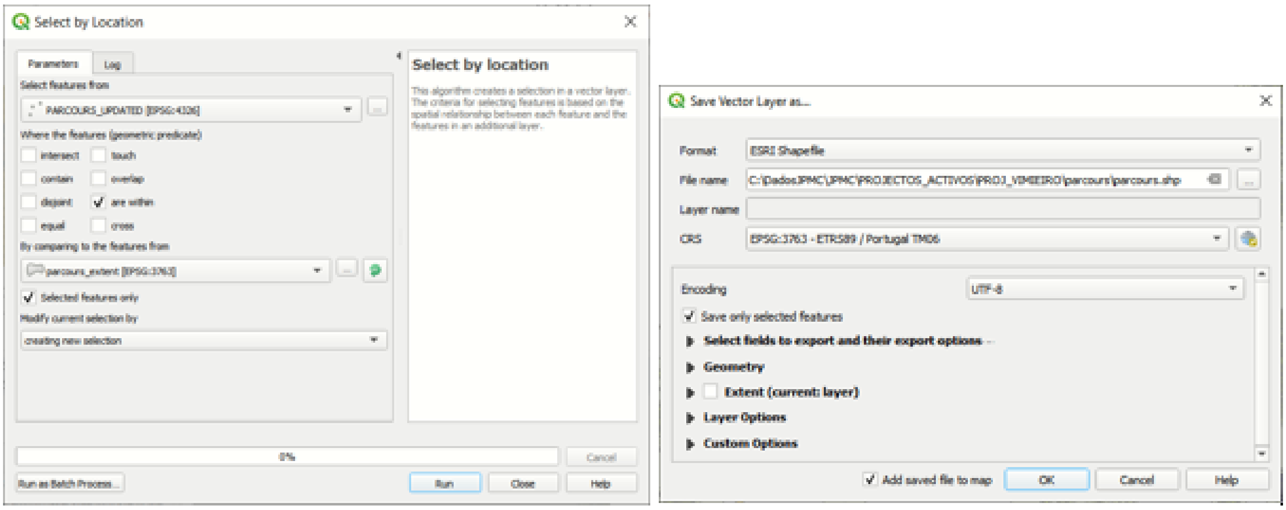



Figure 16: Selection of points by location and export of data to ETRS89

The following figures show the behaviour of the sheep, represented by points, without excluding the movements which are inside the sheepfold (on the right), as well as their behaviour, while eliminating the movements inside the sheepfold (on the left), as shown in.the Figure 17.

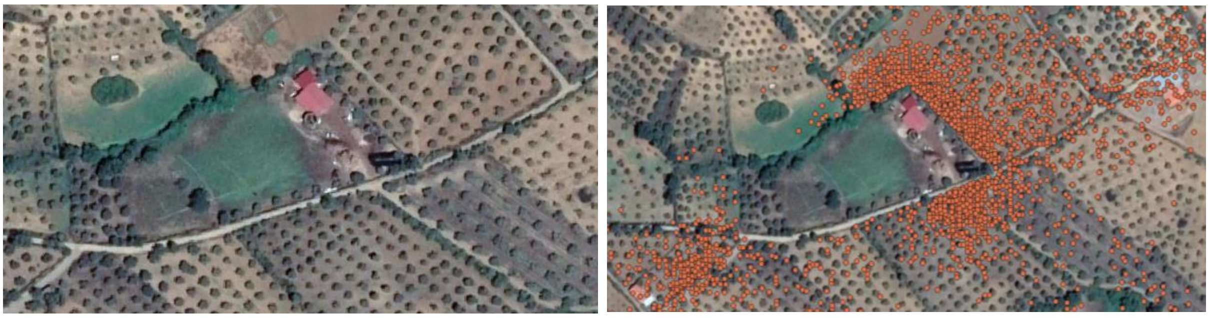


Figure 17: Movement inside the sheepfold eliminated

After recording the movements of the three sheep from December 6, 2019 to June 6, 2020, as well as the realization of the vegetation map of Bragança, it is necessary to overlay the data to identify exactly the grazing study area that interests us for this project.

## Geographical data overlay

We export to raster the vegetation map of Bragança (obtained from COS2018) by ROI extent, with 5-meter spatial resolution. The choice of the 5-meter spatial resolution was a compromise between the characteristic mosaic of the vegetation map, with the speed of movement of the animals every 5 minutes, and also, the processing capacity of the geographic information system.

The output range must be defined in the form (xmin , xmax, ymin, ymax), and in our case these values are equal to: 88500, 92900, 206850, 210450 respectively.

We extract a portion of COS2018 by the limits of the ROI and we convert the polygons to raster (Rasterize QGIS tool) with 5-meter spatial resolution (Figure 18). The result of the obtained raster layer is a temporary file which must be saved under the name COS2018_v1_VIMIEIRO_raster.tif and which effectively limits our study region.

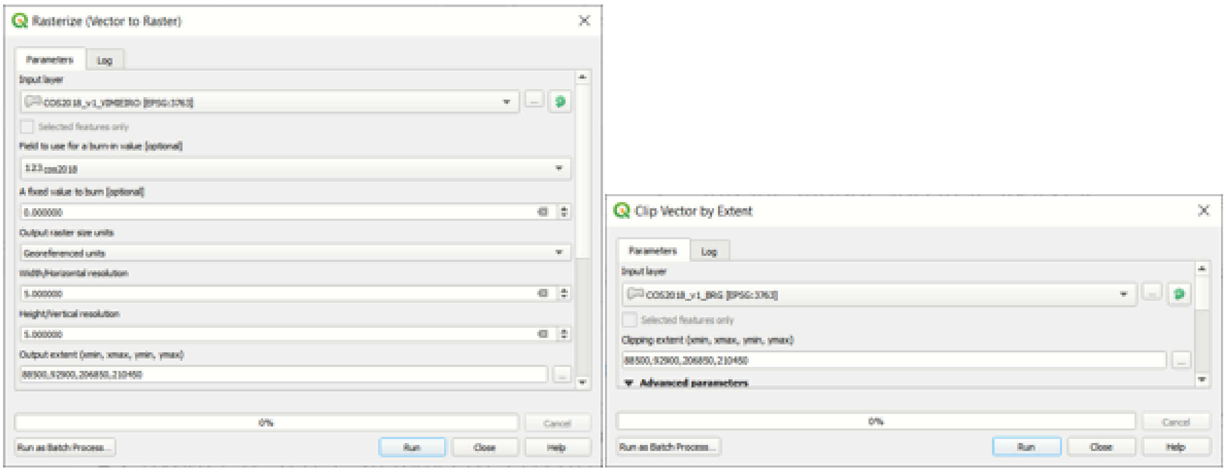



Figure 18: Rasterize and Clip Tools

### *Extract raster values to points*

To include all the information about land use to each grazing point we used the QGIS Point sampling tool PLUGIN (Figure 19) (https://plugins.qgis.org/).

Note: This plugin requires that both layers have the same CRS. Both layers are presented in CRS ETRS89, so we need to export the raster values from COS2018_v1_VIMIEIRO_raster.tif to the points PARCOURS_RASTERIZE.SHP using this Point Sampling Tool to get the rasterized path (PARCOURS_RASTERIZE.SHP.

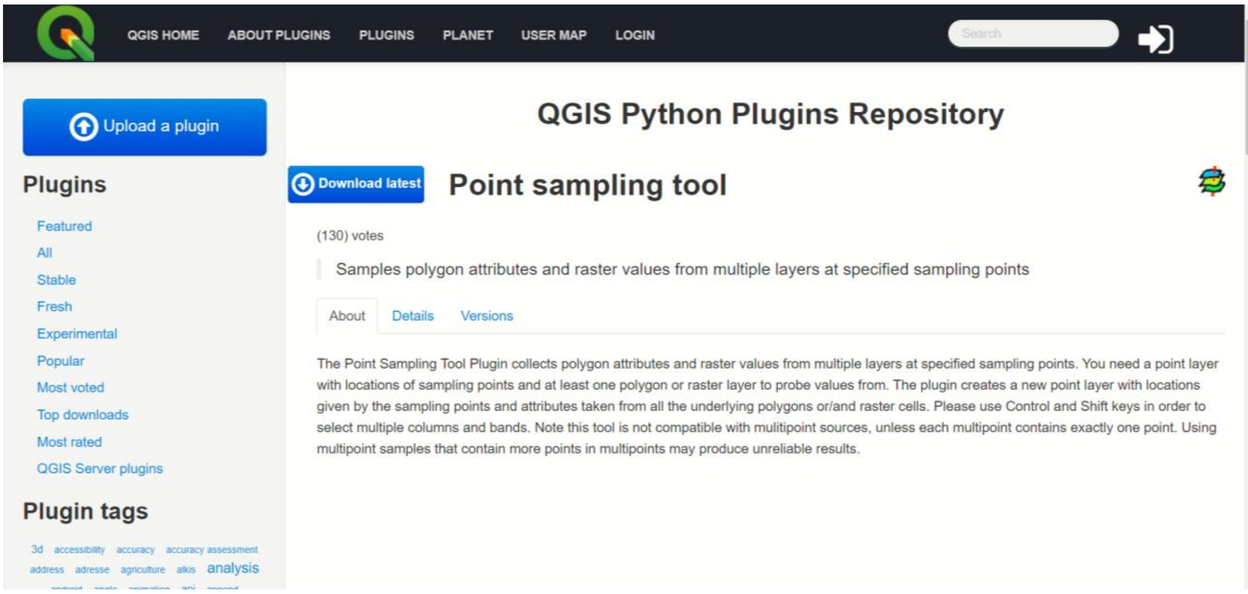


Figure 19: QGIS Python Plugins Repository purpose

The resulting ShapeFile, PARCOURS_RASTERIZE.SHP, has only one column with the value of the land use class in real numerical format (Figure 20). To be associated to ShapeFile PARCOURS.SHP then to COS2018_V1_VIMIEIRO.SHP, to include the remaining missing information, it is necessary to create a new column "cos2018" in 4-digit integer format and to delete the original column "Rasterized" (Figure 21).

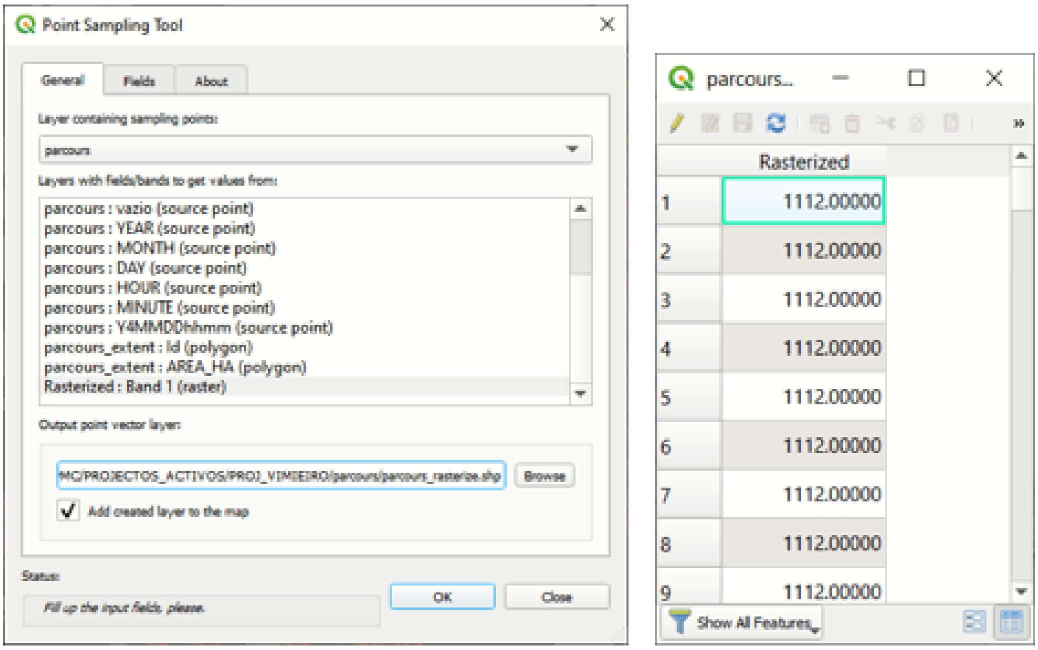


Figure 20: Steps to follow in the Point Sampling Tool

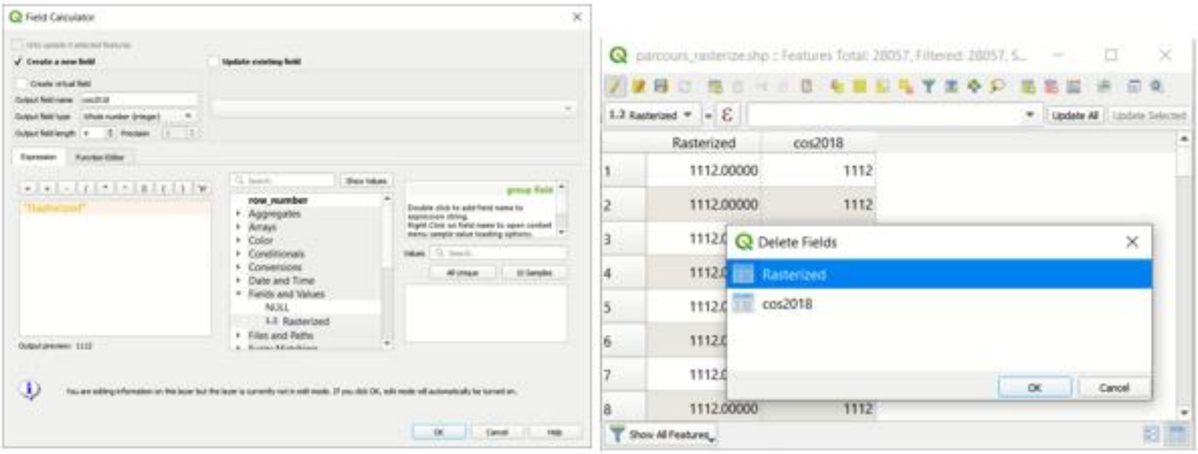



Figure 21: The use of "Field Calculator" tool to create a new column

## Alphanumeric data overlay

### *Vegetation data union*

The union between relatable tables through common fields is a frequent task in Geographic Information Systems (GIS). The spatial intersection of the points with the PARCOURS_RASTERIZE.SHP (Join Attributes by location QGIS tool) allows to include the "cos2018" field that will be used to establish a one-to-one connection with the COS2018_VIMIEIRO.shp table, in order to add detailed information.

In this case, the intersection of the grazing points and the rasterized COS2018 will result in a temporary table (Figure 22).

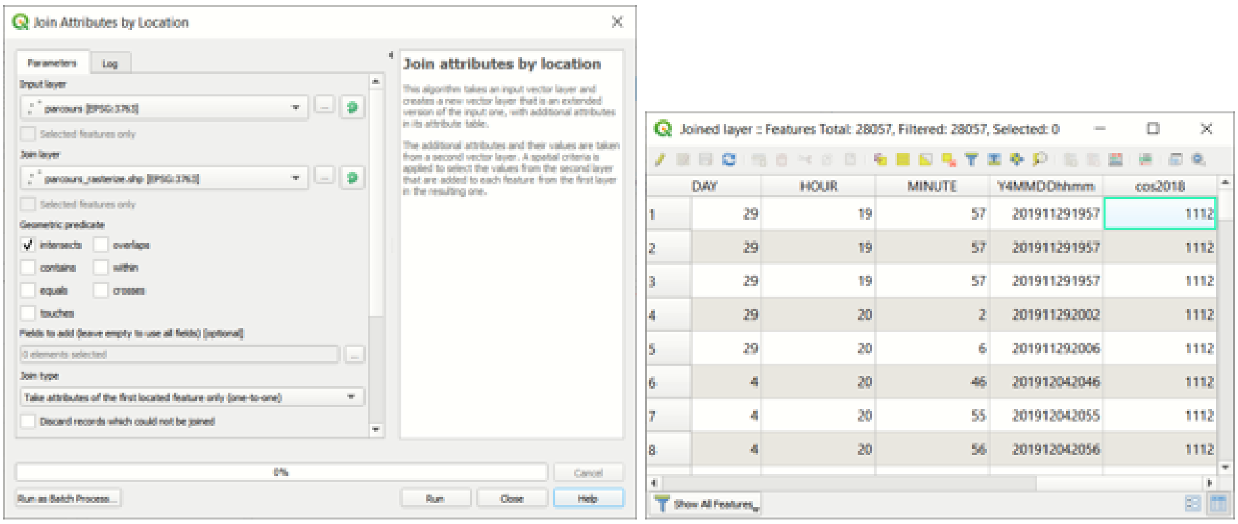



Figure 22: Join Attributes by Location's tool

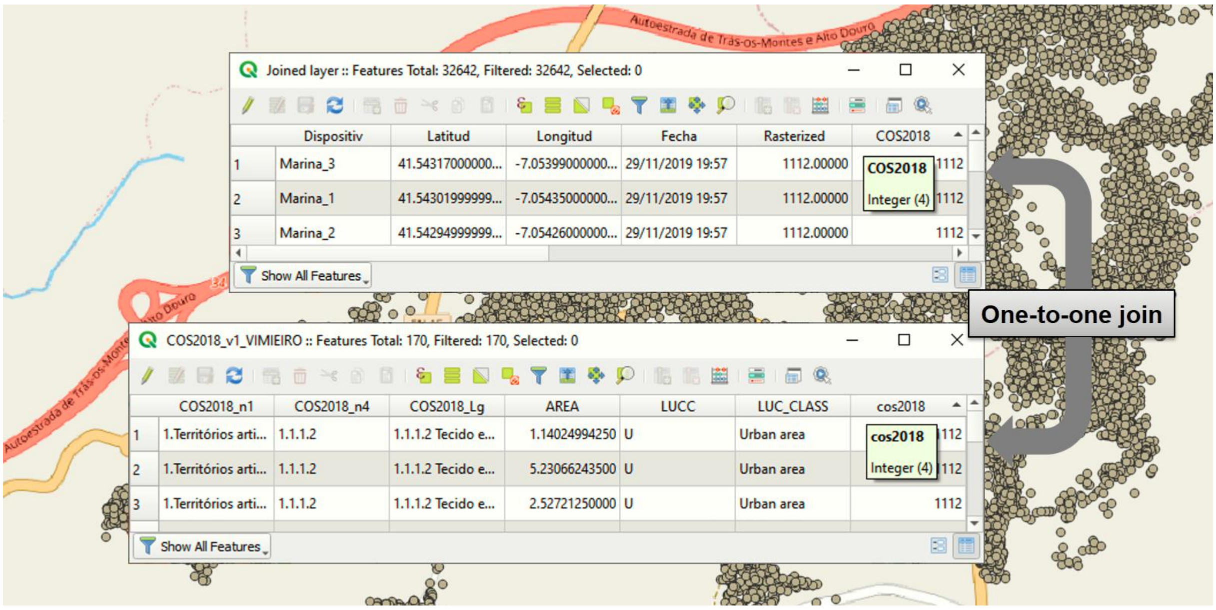



Figure 23: Result obtained from the first link

Joining tables is now possible because they both contain the COS2018 field, with which they can establish a one-to-one connection using the "Join Attributes by Field Value" QGIS tool (one-to-one), between the newly created temporary table and the Land Use and Occupancy Classes table (COS2018_V1_VIMIEIRO.SHP), by the COS2018 fields (Figure 24).

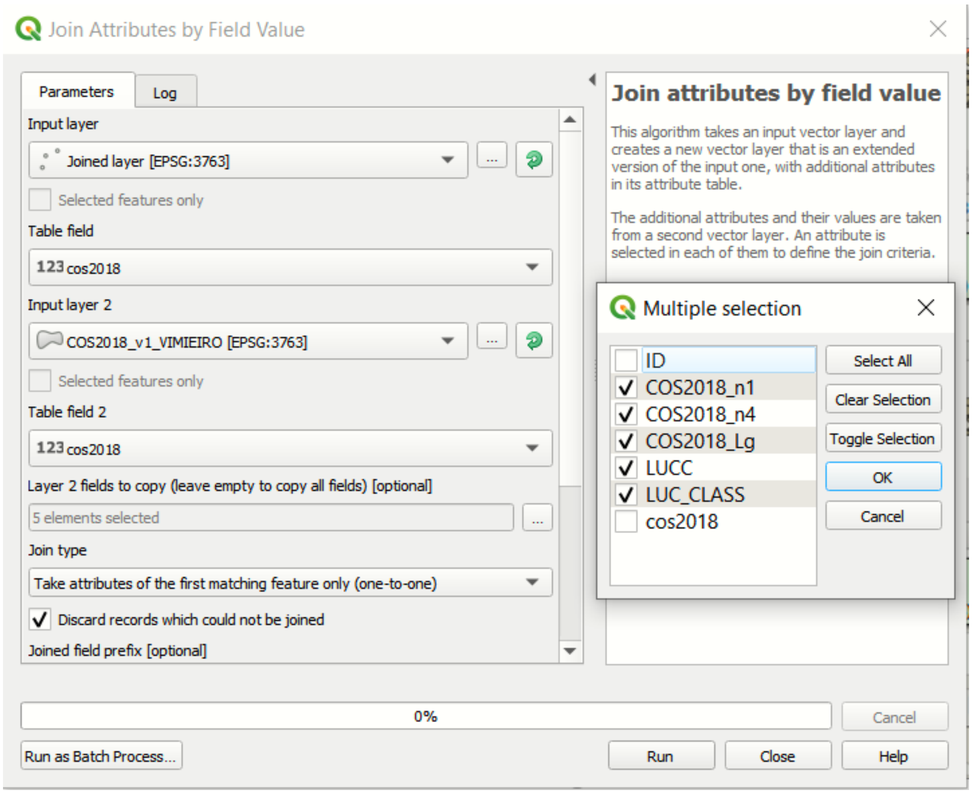


Figure 24: Join Attributes by Field Value's Tool

Temporary files should be exported as permanent files (PARCOURS_COS2018.shp and PARCOURS_COS2018.XLSX).

As new data is collected, daily or weekly, new records are added. By repeating the procedures explained in the previous points in QGIS, the Excel file PARCOURS_COS2018.XLSX is updated.

Simply open the Excel file COURSE_COS2018.XLSX , copy the new records, and paste them into the Excel file COURSE_COS2018_CONSULTA.XLSX.

Although the animal records have been removed from the barn, it should be investigated whether there are any impossible records, i.e. at night and early morning. Only the values of livestock can be taken into account, i.e. they leave the barn and even return.

***Climatic data union***

Additionally, in order to improve understanding the use of the territory, it was necessary to add data related to the temperatures and the precipitations of the Region to analyse the relationship between the use of grazing areas and climate variability. For this, we followed the meteorological information from the automatic station of the ESAB.

Considering that the climatic data were made available at hourly intervals, and the grazing data are 5-minute intervals, we considered a grouping of the climatic data daily, making it possible to obtain mean, minimum and maximum values of temperature and occurrence or not of precipitation. Thus, a field common to both tables was created that allows daily grouping and also hourly grouping. The hourly grouping implies the creation of the field that concatenates year, month, day and hour (YYYYMMDDHH). The daily grouping implies the creation of the field that concatenates year, month and day (YYYYMMDD). Common fields now allow the connection between tables.

## Statistical analysis

An analysis of variance (ANOVA) was fitted using the ANOVA procedure of SYSTAT to evaluate the effects of the month on the intensity of land use (Annual Crops (AC), Grazed Forest (GF), Permanent Crops (PC), Shrublands (S), Ungrazed Forest (UF) and Urban (U). Means, which showed significant differences at the probability level of $p < 0.05$, were compared using Turkey’s test. Principal component analysis (PCA) in the SYSTAT was applied to evaluate multivariate land use utilisation and climatic variables (493 samples × 15 variables).

# 4. Results

In this chapter, the results will be presented in order to explain, the classes of land use most used by sheep flock of Vimieiro, from the 6th of December until the 6th of June (6 months of monitoring).

The first result concerns the creation of the vegetation map, which is the key element of our work, since this map will be used to identify the different land uses, to limit the ROI and then to define the home range of flock. The concept of home range was introduced by Burt in 1943, and corresponds to the area in which an animal lives and moves to graze, breeding and hunting in the case of carnivorous. The information obtained from the GPS collars, allowed identifying: the duration of grazing circuits, the variation over the months and the intensity of use of each land use class. These results will permit us to understand the behaviour of sheep over the months, which is strongly influenced by the availability of forage classes and the routes chosen by the shepherd, also probably influenced by the daily weather conditions.

## 4.1 Land Use Classes of Bragança Region

The different land use classes identified on the Table 1, referring to the nomenclature of the COS2018 map for the classification, and by choosing an adequate symbology that facilitates the visualization, allowed us to realize the map's occupation land use by using QGIS software, which is presented in the Figure 25.

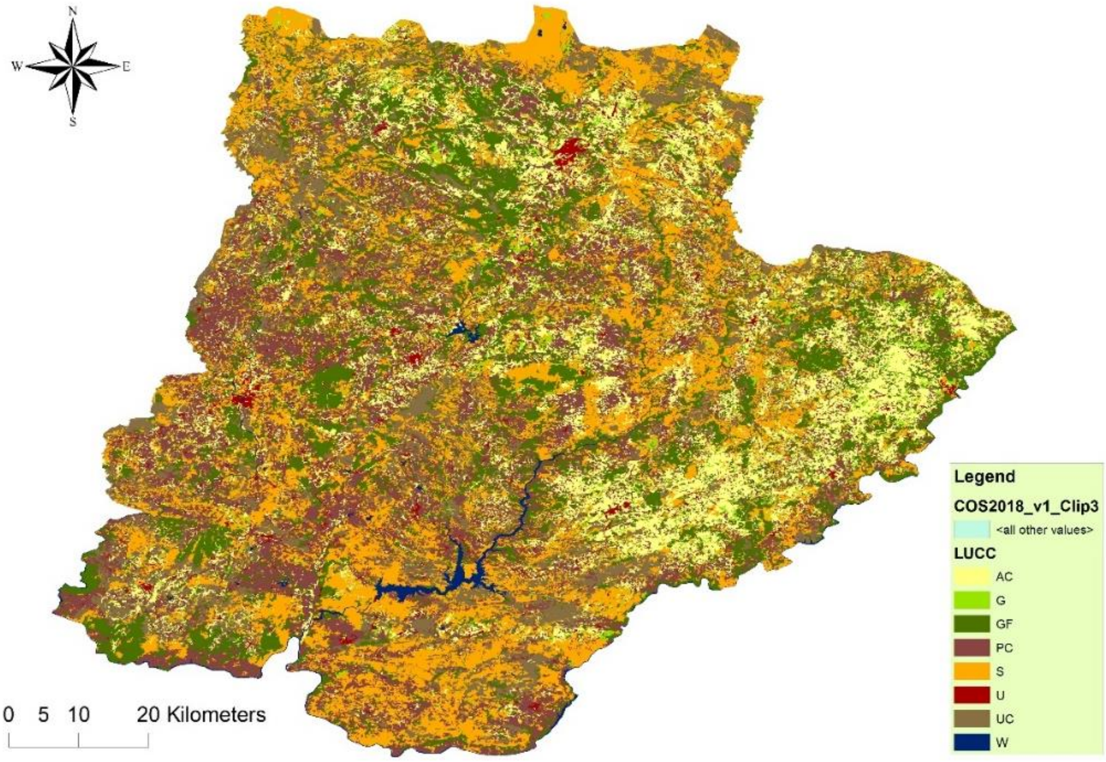


Figure 25: Land use classes of the district of Bragança (QGIS Software)

Table 2: Area and percentage of each Land Use Classes (LUC) in Bragança Region

| Land Use Classes (LUC) | AREA per unit (Ha) | % |
|---|---|---|
| Annual Crops (AC) | 98 624 | 14.22 |
| Grasslands (G) | 17 012 | 2.45 |
| Grazed Forest (GF) | 116 623 | 16.81 |
| Permanent Crops (PC) | 144 683 | 20.86 |
| Shrublands (S) | 169 797 | 24.48 |
| Urban (U) | 35 256 | 5.08 |
| Ungrazed Forest (UF) | 103 529 | 14.92 |
| Water (W) | 8 168 | 1.18 |
| Total | 693 693 | 100 |

The results obtained above show that Bragança Region is diverse in land use composition. The Shrublands are the class most abundant (169 797 ha, 24.48% of total area), followed by permanent crops (144 683 ha, 20.86%); grazed forest (116 623 ha, 16.81%); and annual Crops (98 624 ha, 14.22%) (Figure 25 and Table 2).

## 4.2 Home range of sheep

After taking the movement of sheep for the sixth months, we put the points referring to the movement into the vegetation map (Figure 25) in order to identify the home range of the flock.

The LUC map of Bragança produced can be cut out according to the ROI, area containing all the movements recorded during this period, and exported as a new map. The Figure 26 shows our ROI, the LUC and all the grazing points recorded during these six months.

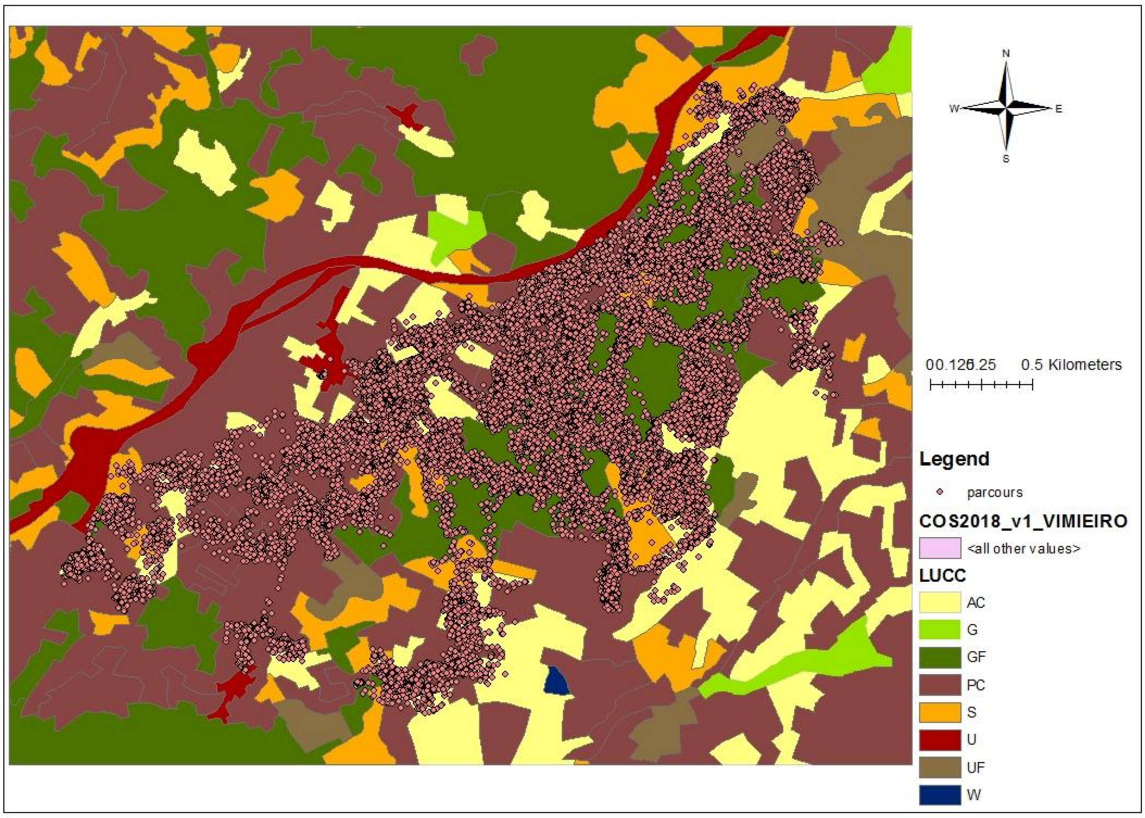



Figure 26: ROI's LUC and grazing points (QGIS Software)

From the map presented in the Figure 26, we notice that during the entire period of the experimentation, the sheep were grazing on the lower side of the region's highway (urban class presented in red color). But the map still contains the upper side. This is because the GIS software allows us to make a rasterization only in a square or rectangular form, and not in any other form.

Table 3: Areas and Land Use Classes (LUC) of the ROI

| LUC of the ROI | Area (Ha) | % |
|---|---|---|
| Annual Crops (AC) | 231 | 14.63 |
| Grasslands (G) | 20 | 1.27 |
| Grazed Forest (GF) | 420 | 26.60 |
| Permanent Crops (PC) | 643 | 40.72 |
| Shrublands (S) | 155 | 9.82 |
| Urban (U) | 49 | 3.10 |
| Ungrazed Forest (UF) | 60 | 3.80 |
| Water (W) | 1 | 0.06 |
| Total | 1579 | 100 |

The Table 3 shows the different land use classes present in the region of interest of our experiment. These results explain that the four most commonly used classes are Permanent Crops (PC) (643 ha, 40.72%) Grazed Forests (GF) (420 ha. 26.60%), Annual Crops (AC) (231 ha; 14.63%) and Shrublands (S) (155 ha; 9.82%).

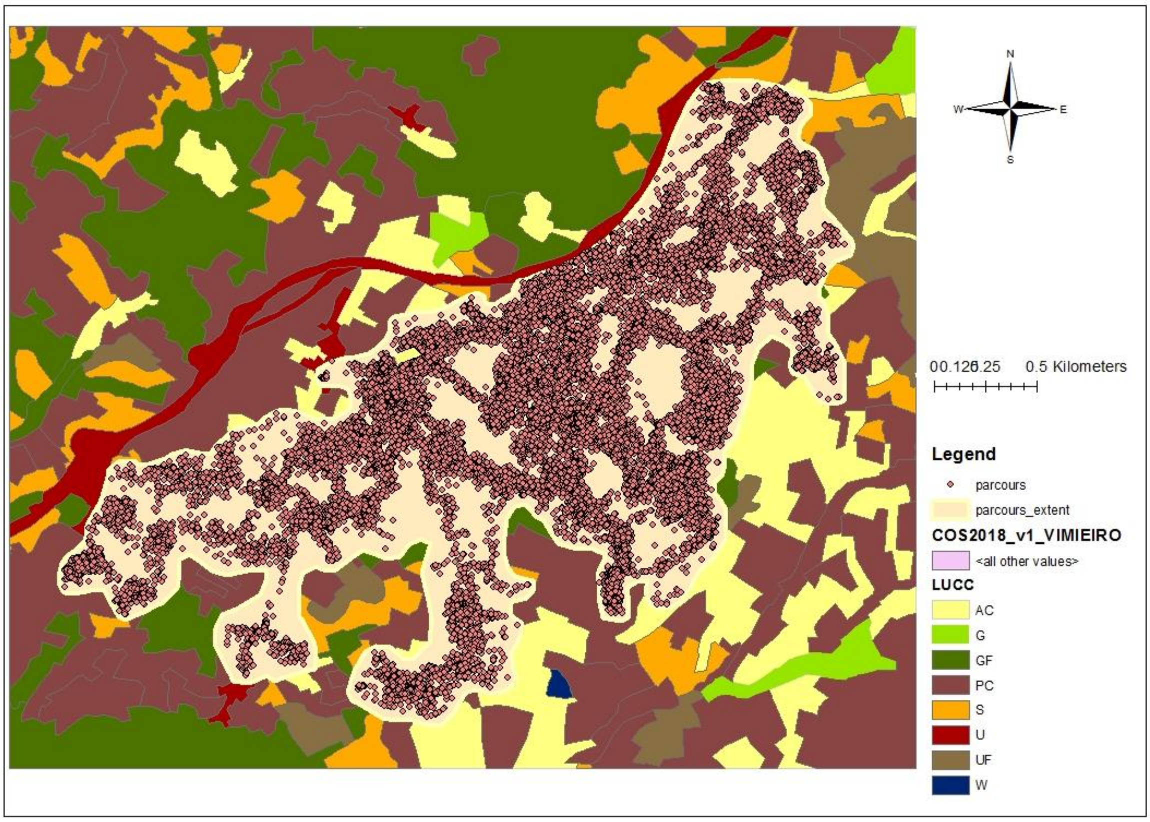



Figure 27: Grazing area during the experimentation (QGIS Software)

The area of the square map rasterized (ROI) equals to 1579 ha (Table 3), but the exact grazing area, where there is only the movement of sheep, in the lower side of the highway, equals to 500 ha (the limites are defined manually by using GIS software) (Figure 27).

## 4.3 Duration of grazing circuits

The duration of sheep grazing circuits varies significantly (p= 0.000) over the months.

In December, the average grazing duration equals to 289 minutes. This value increases progressively and reaches 307 minutes in January and 345 minutes in February. Thereafter, the result obtained shows that this value decreases again and goes down to 305 minutes in March. However, in April, the average grazing time reached the maximum (410 minutes) and decreases slowly to 383 minutes in May and 329 minutes in June (Figure 28).

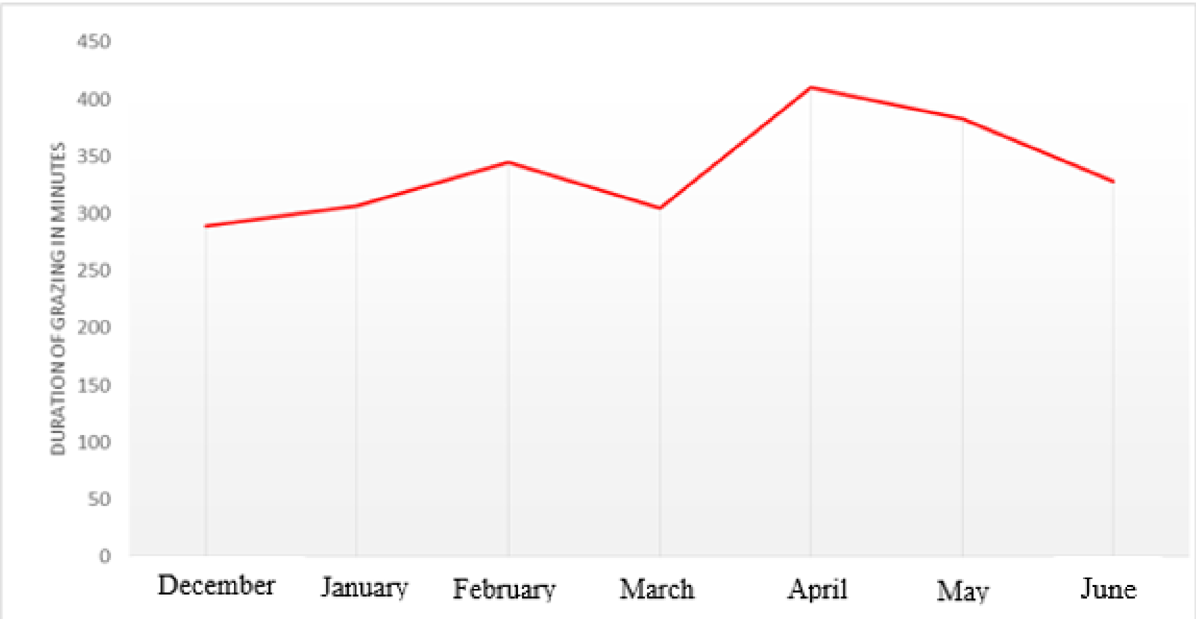


Figure 28: Duration of grazing by sheep from December 6, 2019 to June 6, 2020

In spring (from April to June), sheep have been grazing bigger circuits than in winter (From December to March). Indeed, in winter, the grazing time does not exceed an average of 6.5 hours of grazing per day, except in a few exceptional days when the grazing time may be longer. When it is raining a lot, the sheep do not graze long distances. It is the case in some days in January, where the duration of grazing did not exceed one hour and half.

Whereas, in spring, the grazing time is well over 8 hours, and can even reach up to 9 hours of grazing per day, seen that the temperature is getting higher, and sheep graze in longer time, and within this time, they can rest under the trees of forests (Figure 28).

## 4.4 Intensity of grazing of each land use

The analysis of variance (one factor - ANOVA) allowed us to understand how the use of the different classes of land use were different or not over the months. The significance values for each of the analysed variables are found in the Table 4.

Table 4: Intensity of grazing in each land use

| Parameter | N | Factor |
|---|---|---|
| | | Month |
| Annual Crops (AC) | 476 | 0.000+++ |
| Grazed Forest (GF) | 476 | 0.000+++ |
| Permanent Crop (PC) | 476 | 0.355 |
| Shrublands (S) | 476 | 0.303 |
| Ungrazed Forest (UF) | 476 | 0.000+++ |
| Urban (U) | 476 | 0.728 |

Some classes vary a lot throughout the year, while others do not. Indeed, significant differences were found for the variables percentage of time spent in the Annual Crops (AC), Grazed Forest (GF) and Ungrazed Forest (UF) classes. While for the percentage of time spent in the Permanent Crops (PC), Shrublands (S) and Urban (U) classes, no significant differences were found.

The Table 5 presents the arithmetic mean ± deviance and the index of p-value of each land use per month, during the experimental period. These values will be used to properly identify the intensity of use of each land use in each month.

Table 5: Grazing intensity for each land use

| Month<br>LUC | Dec. | Jan. | Feb. | Mar. | Apr. | Ma. | Jun. |
|---|---|---|---|---|---|---|---|
| Annual Crops (AC) | 10.31[c] ( ± 12.88) | 18.36[b] (±17.2) | 16.32[b] (± 14.82) | 24.56[a] (± 20.06) | 23.46[a] (± 21.38) | 17.03[b] (± 20.41) | 6.81[c] (± 7.95) |
| Grazed Forest (GF) | 38.72[ab] (± 21.92) | 30.75[b] (± 22.34) | 27.64[b] (± 23.22) | 25.50[b] (± 22.91) | 31.71[b] (± 25.41) | 36.18[b] (± 26.00) | 48.78[a] (± 24.52) |
| Permanent Crop (PC) | 42.13[a] (± 20.47) | 41.56[a] (± 21.12) | 45.81[a] (± 21.74) | 40.68[a] (± 21.53) | 36.68[a] (± 19.12) | 39.56[a] (± 22.46) | 38.04[a] (± 26.95) |
| Shrublands (S) | 7.79[a] (± 7.61) | 8.03[a] (± 8.33) | 8.19[a] (± 6.74) | 7.94[a] (± 10.01) | 6.71[a] (± 8.36) | 5.73[a] (± 11.98) | 4.89[a] (± 5.61) |
| Ungrazed Forest (UF) | 0.17[b] (± 0.7) | 0.16[b] (± 0.54) | 0.07[b] (± 0.37) | 0.33[b] (± 1.24) | 0.06[b] (± 0.24) | 0.05[b] (± 0.30) | 1.29[a] (± 3.10) |

Different letters indicate significant differences between months concerning the time spent in the same land use.

From the table below, the most used classes by sheep, during the studied period, are Permanent Crop (PC), followed by Grazed Forest (GF) class. The average monthly usage of each of these two classes is high throughout these six months of experience. The usage of the Grazed Forest (GF) is significantly different over the months, while the Permanent Crop (PC) class is not.

In the third place comes the use of the Annual Crop (AC) class. The time spent in this class is significantly different over the months (Table 5), varying from 10.31% of use in December, to 25.94% in March. However, the percentage of use of this class decreases significantly from March, and reaches a percentage of use equal to 6.81 in June.

The time spent in Shrublands' (S) class by sheep during the studied period did not show significant variation over the months. The time spent in the Ungrazed Forest (UF) is, as expected, close to zero, but shows significant differences of usage across the months.

The Figure 29 explains more the results obtained before and presents the grazing intensity in the main classes of the grazing circuits done by sheep and guided by the shepherd.

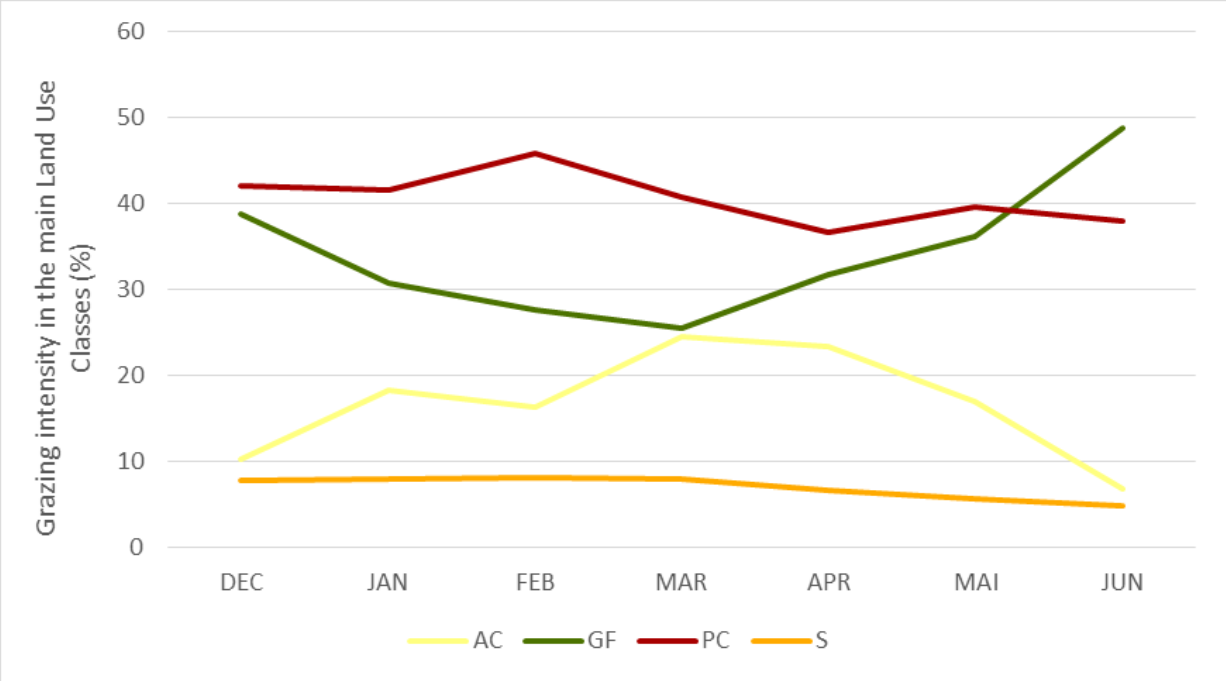



Figure 29: Percentage of grazing of Land use classes during the months

The two classes, Permanent Crops (PC) and Grazed Forest (GF), are the most used by sheep. From April, these classes reach close values. However, in June, last month of spring and beginning of summer, the use of the Grazed Forest (GF) becomes more intense (48.78% for GF while 38.04% for PC).

Indeed, the percentage goes from 42.13% of use, during the month of December, and reaches a peak of 45.81% in February. This percentage dropped again during the month of March (42%), but is still remaining the highest percentage of consumption during the season.

These results will lead us to better explore the grazing areas most used by sheep and to indicate if the difference in use of the same class over the months is significant or not, noticing that the grazing routes are always identified by the shepherd and the forage availability.

***Seasonal comparison***

From December to March (winter season), and according to the Table 5 and Figure 30, it turns out that the Permanent Crops (PC) and Grazed Forest (GF) classes, are the most consumed by sheep during this period, where they reached a seasonal maximum of 42.13% and 38.72% of usage respectively.

From April to June (spring season), the percentage of use of Permanent Crops (PC) and Grazed Forest (GF) classes gradually decreased compared to the previous season, with 37.77% and 31.16% of usage respectively . Indeed, although the time spent in Gazed Forest (GF) class is very high in June (48.78%) (Figure 29), when we combine the winter and spring months, the percentage of usage of the Permanent Crops (PC) remains higher.

Concerning the Annual Crops (AC) class, its usage is getting higher over the seasons, where the percentage of usage went from 10.31 in winter, and reached 23.05% of usage in spring.

The time spent in the Shrublands (S) and Ungrazed Forest (UF) classes is low in both seasons (7.79% and 0.17 % respectively in winter; 0.06% and in spring).

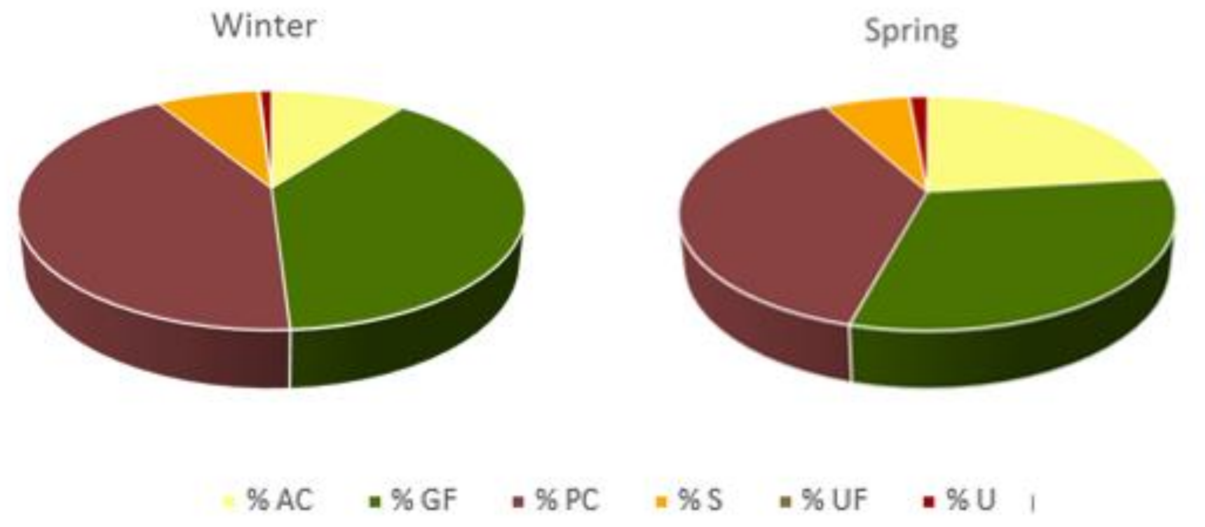



**Figure** 30: Importance of the different classes of use in winter and spring itineraries.

The two classes, Permanent Crops (PC) and Grazed Forest (GF), occupy the highest percentage of consumption by sheep in both studied seasons. Consequently, in spring, the consumption of Permanent Crops (PC) and Grazed Forest (GF) classes decreased compared to the previous season, but is still reaching the highest values. While the time spent in Annual Crop (AC) class is occupying the third place of consumption in both season.

## 4.5 Availability of classes in the territory and their use

The Table 3 allowed us to identify the available percentage of the land use classes present in the Region of Interest (ROI), and the data obtained from the GPS collars permitted to determine sheep's positions during the experimental period (Figure 26). These information allowed us to obtain the result presented in the Figure 31, that shows the percentage of grazing in each land use in relation to the availability of resources.

The Figure 31 shows that the two classes, Grazed Forest (GF) and Permanent Crops (PC), have the highest areas of occupation in the Region of Interest (ROI), and their consumption too. Indeed, Permanent Crops (PC) represents 40.72% of the territory, and its consumption during the experimentation period amounts to 40.64% of the available forage. Same for the Shrublands (S) class, where there is 9.82% of area available and a percentage grazed of 7.04.

Consequently, the Annual Crops class (AC) represents 14.63% of the total area available from the Region of Interest (ROI), but its consumption during this period reached 16.69%, which means that the percentage grazed is higher than the percentage available. As for Grazed Forest (GF), its surface area represents 26% of the Region of Interest (ROI), and its consumption represents 34.18%.

Concerning the Urban (U), Grasslands (G) and Ungrazed Forest (GF) classes, their availability at the level of the grazing area is low, so is their consumption.

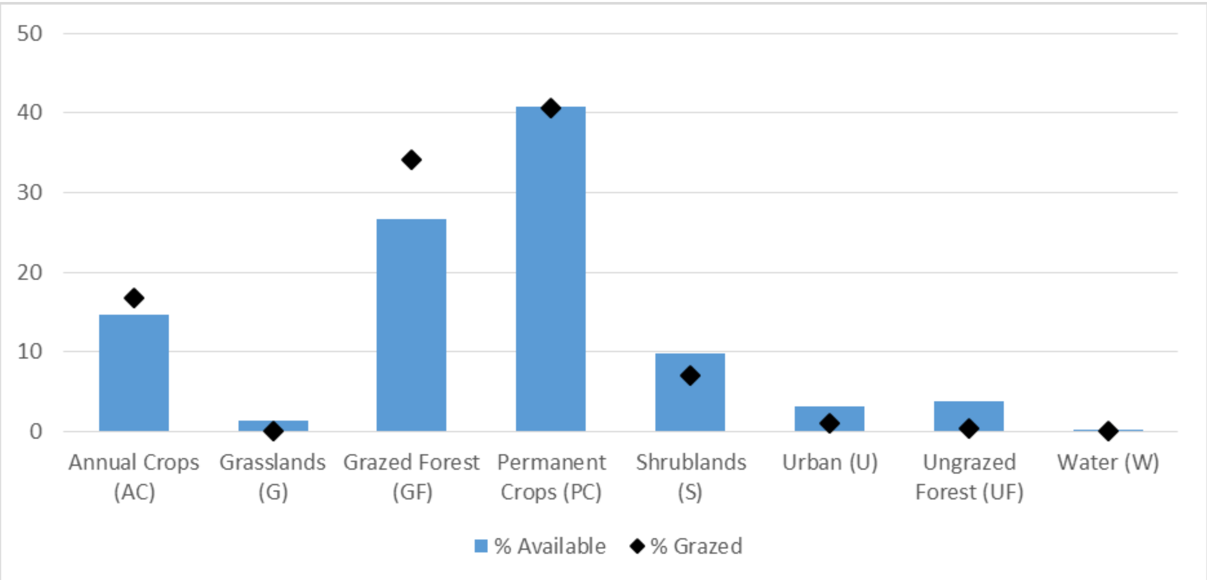



Figure 31: Availability of LUC in the ROI and their consumption

## 4.6 Multifactorial perspective (PCA)

In order to understand the relationship between the climatic conditions and the variation of the time spent in each land use, a Factorial Analysis (PCA) was performed, with 15 variables (Average Temperature (T), Maximum of Temperature (MAX), Minimum of Temperature (MIN), Permanent Crop (PC), Grazed Forest (GF), Annual Crops (AC), Shrublands (S), Duration of Grazing and Rain) and 493 samples.

The total of the percentage of variance explained by the three components is 64.31%, the first axis explains 30.915%, the second 17.76% and the third 15.77% (Table 6)

Table 6: Variance Explained by Components (SYSTAT 13)

| Factors | | |
|---|---|---|
| 1 | 2 | 3 |
| 30.915 | 17.762 | 15.775 |

The variables of the temperature (average, maximum and minimum) were the most important in relation to the first axis, as they are positively related with the duration of grazing circuits and the time spent in Grazed Forest (GF) class. When the temperature is high, for example, the grazing time is longer and the use of Grazed Forest (GF) is more intense (and vice versa) (Figure 32). The second axis seems to be related to the organization of the territory, that is, the Grazed Forest class (GF) (-0,913) is negatively correlated with the agricultural land uses (Permanent Crops (PC) and Annual Crops (AC)). The third axis separates the use of the Permanent Crops (PC) (-0.847) from Annual Crops (AC) (0.686), confirming the information taken from the second one (Figure 32).

Table 7: Component Loadings

| | 1 | 2 | 3 |
|---|---|---|---|
| T | 0.961 | 0.230 | -0.071 |
| MAX | 0.886 | 0.181 | -0.088 |
| MIN | 0.844 | 0.229 | -0.001 |
| GF | 0.357 | -0.913 | 0.097 |
| PC | -0.231 | 0.422 | -0.847 |
| AC | -0.088 | 0.477 | 0.686 |
| S | -0.218 | 0.467 | 0.350 |
| Duration of grazing | 0.336 | -0.041 | 0.225 |
| Rain | -0.115 | -0.009 | 0.193 |

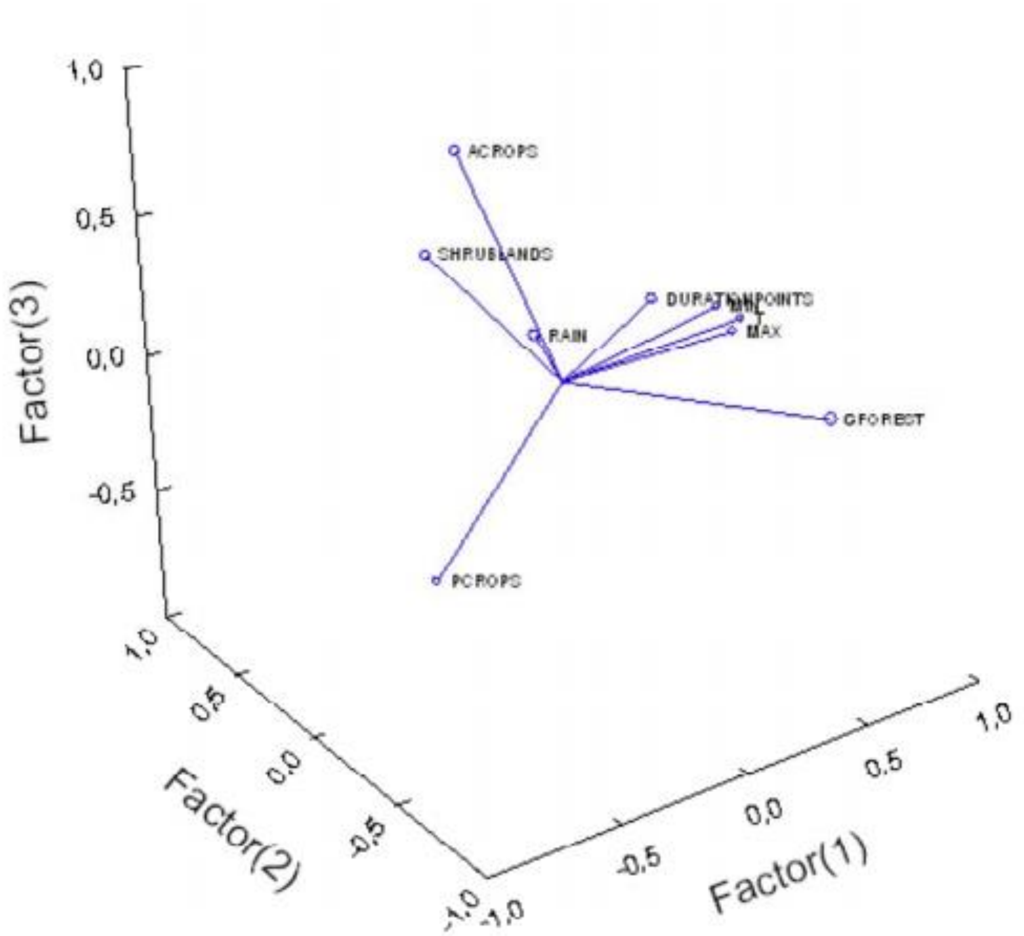



Figure 32: Factor loading plots (SYSTAT 13)

# 5. Discussion

The main objective of this study is to evaluate how the Vimeiro sheep herd uses the available land, and to establish the relationship between land use and herd use. It was also very important to analyse how seasonal variations influence land use by the animals. Our approach is based on the evaluation of the time spent in each land use, recorded at 5-minute intervals. These data are obtained through the use of GPS collars, a proved and mature technology to track animals, combined with the use of GIS software (QGIS), to realize the Land Use classes' map of the our study area. Moreover, the statistical analysis were calculated by SYSTAT software, and the climate data was obtained from the ESAB, in order to study the effect of climate on the usage of the territory.

The starting hypothesis is the following: if the herds use the landscape differently from its composition, then there is a grazing strategy that depends on its composition. To evaluate this hypothesis, the following steps were taken:

- An analysis of the duration of the grazing circuit per month;
- An analysis of the percentage of each land use on the territory, and the time spent in each land use (in percentage) during the grazing circuits;
- An assessment of grazing intensity for each land use; and
- An analysis of the effect of climate (temperature and precipitation) on the choice of routes and grazing areas

Comparing the grazing circuits obtained in this study with other similar works in Trás-os-Montes region, it turns out that the duration of grazing showed almost same length values than those found by Castro (2004). These differences may be due to different local conditions. On the other hand, these results showed lower length values than the study reported by Schlocht et al. (2009) in northern Oman, due to the different ecological conditions (total annual precipitation of 100-340 mm; average annual temperature 18.1ºC, with a minimum of 3.6 ºC and a maximum of 36.3ºC).

Regarding the composition of the territory, the Land use Classes map realized shows that the four most commonly classes in the Region of interest are Permanent Crops (PC), Grazed Forests (GF), Annual Crops (AC) and Shrublands (S).

Concerning the usage of the territory, in both seasons, Permanent Crops (PC) and Grazed Forests (GF) classes represent the most grazed classes throughout the duration of the experiment. Indeed, in spring, sheep spend longer periods of the day grazing than in winter, and can walk up to eight hours a day, while hiding in the shade of the forests to protect themselves from the sun and rest. In addition, the sheep harvest Annual Crops (AC), Shrublands (S) and Ungrazed Forests (UF), depending on the timing of resource availability. For instance, sheep are grazers, preferring to graze close to the soil surface (Jonsson, 2010; Castro et al., 2016), which can explain the results of our study.

Grazing behaviour depends on the periods of daylight, which coincide with the activity patterns of sheep under extensive farming conditions, as generally described in the literature (Askins and Turner 1972; Lu 1988). Our results showed that grazing duration varies seasonally, being highest in spring. This can be explained by the long resting time during the hottest periods of the day, as sheep are particularly sensitive to high temperatures and solar radiation (Castro et al., 2007), and night grazing is therefore more beneficial for sheep, helping them to improve their physical condition, reduce heat stress and increase fodder consumption and production (Marai et al., 2007).

The results obtained concerning the duration of sheep grazing showed a sudden decrease during the month of March 2020. Indeed, this month was the first month of confinement, caused by the presence of the COVID-19. The shepherd was then making short grazing circuits because of the pandemic, which then made the average grazing time during this month low.

The ideal grazing route chosen by the shepherd aims to meet a set of needs demanded by the flock. Thus, the location of the herds, the water points, the availability of roads and moorings, very significantly determine the use of resources. The routes taken by the sheep are selected according to all the restrictions and opportunities offered by the landscape. It can be said that the registers depend closely on territorial organization, adapting to changes that may occur.

The results obtained confirm that the routes are conditioned by seasonal variations in environmental conditions (maximum and minimum temperatures, rainfall, etc.). Faced with the need to meet their basic needs during their daily routes, herds seek seasonal resources that are more compatible with their needs.

The three collars were used to take into consideration the problems that may arise, which was very useful because we encountered several problems with the quality of the information obtained but also in terms of the quality of the locator and in terms of battery.

The high use of permanent crops and pastured forests in February is due to the fact that these classes are composed of several subclasses characterized by a great diversity, and sheep then have many grazing opportunities. In addition, there are often complex farming systems around the village, so the sheep begin their grazing journey with these systems. It should be noted that the choice of routes is made by the shepherd, since he knows the area well and is already aware of the availability of fodder.

The results show that the time spent in the Annual Crops (AC) and Forest Pasture (FG) classes far exceeds the percentage available, meaning that these classes are preferred and desired by sheep but not available in sufficient quantity to meet their needs. This is in contrast to the Prairie (G) and Shrub (S) classes, which are available for consumption, but their consumption is very low.

The forests provide shade with low temperatures during hot months such as June. As we know, sheep are particularly sensitive to high temperatures and solar mediation (Marai et al., 2007). For example, they rest in these forests during the hot hours of the day, while grazing early in the morning and at night. (Castro et al., 2016). Annual crops are available but less used by sheep; this may be because the sheep are not interested in this class or the shepherd does not allow them enough time to graze.

The forest can also be used for conversion to other land uses. Therefore, they can be considered as a corridor within the sheep range to reach other land uses.

Grazing activity is influenced by the climatic conditions of the year, as these conditions affect the availability of food resources and therefore the choice of land uses by the animals. The effect of the season is evident in the case of permanent crops and grazed forests. Indeed, this land use is more chosen by sheep in winter, while the other classes are little used. According to Castro et al (2004), sheep are highly dependent on agricultural activities.

For both classes: Urban and Ungrazed Forest, they are not grazed, since the grazing circuits are always on the lower side of the highway, and all the land is grazed crops and forest, but not urban.

Achieving all these objectives, gradually, gave me a good understanding of how to collect data with GPS collars, a proved and matured technology tool to track animals, and how to process data and information from it, using GIS and statistical software, such as QGIS and SYSTAT.

In the coming months, the same work will be carried out on an ongoing basis, in an even more thorough manner. Indeed, in our area of interest, an area has been surrounded by fences, where the sheep will remain there freely, without being guided by the shepherd. In this case, the information required will be increasingly secure and impartial.

We had already started to do this step of classifying satellite images, but given the pandemic and the unfavourable conditions, we were unable to return to the field to check whether the classification carried out was correct or not.

In this way, it would be possible to clearly identify sheep preferences on a monthly and seasonal basis, which will help in proper planning and management of the territory, in order to design pasture fire prevention programs and to require local grazing intensification.

# 6. Conclusion

Tracking sheep with GPS collars has greatly enhanced research and development of tools to improve the distribution and uniformity of grazing by livestock allowing them to quantitatively measure changes in movement. This technology, combined with GIS, allows researchers to conduct studies of pasture distribution traits and potentially use selection to improve the utilization of land use classes by livestock.

The results of this study contribute to the knowledge of traditional sheep farming systems in north-eastern Portugal. The information obtained from GPS collars, combined with QGIS and SYSTAT software, shows that sheep do not use the landscape randomly, their guidance by the shepherd throughout the day allows them to have rationality in their use since the proportion of each land use in the circuit is different from its proportion in the territory. Sheep prefer Permanent Crops (where olive trees are used most), followed by Grazed Forest and Annual Crops in the two seasons studied (winter and spring), with different percentages, meaning that these classes show significant differences in use over the months. An important relationship exists between the landscape and the pastoral system. The landscape influences the grazing system through its composition and configuration, and this grazing system enhances and conserves the landscape as noted by several authors.

Finally, seasonal parameters collected during the course of this work, allowed more significant and explicit results to be obtained. Precipitation, temperature, and vegetation availability are substantial factors for the classification of tracks on a seasonal basis; in order to understand and detail track strategies.

It should be noted that this study was only applied during 6 months of experimentation. In the future, this project will continue to be evaluated and monitored, which will allow a better understanding and analysis of the monthly preferences of the sheep, over the months and over the years, in relation to seasonality.

# 7. References

Agreil, C, and M Meuret. 2004. "An Improved Method For Quantifying Intake Rate And Ingestive Behaviour Of Ruminants In Diverse And Variable Habitats Using Direct Observation". Small Ruminant Research 54 (1-2): 99-113.

Aguiar C., O. Rodrigues , J. Azevedo, T. Domingos. 2009. "Montanha.". Ecossistemas e bem-estar humano: avaliação para Portugal do Millennium Ecosystem Assessment: 295-339.

Askins, G. D., and E. E. Turner. 1972. "A Behavioral Study Of Angora Goats On West Texas Range (Un Estudio Sobre Las Actividades De Cabras De Angora En Un Pastizal Natural En El Oeste De Texas)". Journal Of Range Management 25 (2): 82 - 87

Azevedo, J. C., C. Moreira, J. P. Castro, and C. Loureiro. 2011. "Agriculture Abandonment, Land-Use Change And Fire Hazard In Mountain Landscapes In Northeastern Portugal". Landscape Ecology In Forest Management And Conservation, 329-351.

Bailey, D. W, Trotter M. G, Knight C.W, and Thomas M.G. 2018. "Use Of GPS Tracking Collars And Accelerometers For Rangeland Livestock Production Research1". Translational Animal Science 2 (1): 81-88.

Barbosa, J. C., and J. Portela. 2000. "O pastoreio de percurso no sistema de exploração de ovinos em Trás-os-Montes." Actas do Colóquio" Montemuro-a última rota da transumância": 95-116.

Barwick, J., et al. 2017. "On-animal motion sensing using accelerometers as a tool for monitoring sheep behaviour and health status." Armidale (Australia): University of New England.

Bellido, M.M., M. E. Sánchez, F. J. M. Diaz, A. R. Vega, and Garcia, F. P., 2001. Sistemas extensivos de producción animal. Archivos de Zootecnia, v. 50: 466-489.

Berckmans, D. 2006. "Automatic on-line monitoring of animals by precision livestock farming." Livestock production and society. Wageningen Academic Publishers, Wageningen, pp 287-295.

Bernáldez, F. G. 1991. "Ecological consequences of the abandonment of traditional land use systems in central Spain." Options Méditerranéennes (15): 23-29.

Bonnet, Olivier J. F., Michel Meuret, Marcelo R. Tischler, Ian M. Cezimbra, Julio C. R. Azambuja, and Paulo C. F. Carvalho. 2015. "Continuous Bite Monitoring: A Method To Assess The Foraging Dynamics Of Herbivores In Natural Grazing Conditions". Animal Production Science 55 (3): 339.

Borchers, M.R., Y.M. Chang, I.C. Tsai, B.A. Wadsworth, and J.M. Bewley. 2016. "A Validation Of Technologies Monitoring Dairy Cow Feeding, Ruminating, And Lying Behaviors". Journal Of Dairy Science 99 (9): 7458-7466.

Braat, L. C. 2018. "Five Reasons Why The Science Publication “Assessing Nature’S Contributions To People” (Diaz Et Al. 2018) Would Not Have Been Accepted In Ecosystem Services". Ecosystem Services 30: A1-A2.

Bradshaw, C. J. A., D. W. Sims, and G. C. Hays. 2007. "MEASUREMENT ERROR CAUSES SCALE-DEPENDENT THRESHOLD EROSION OF BIOLOGICAL SIGNALS IN ANIMAL MOVEMENT DATA". Ecological Applications 17 (2): 628-638.

Buerkert, A., and E. Schlecht. 2009. "Performance Of Three GPS Collars To Monitor Goats’ Grazing Itineraries On Mountain Pastures". Computers And Electronics In Agriculture 65 (1): 85-92.

Caja, G., Ghirardi, J.J., Hernandez-Jover, M., Garain, D. 2004. "Diversity of animal identification techniques: From ‘fire age’to ‘electronic age’." ICAR Technical Series 9: 21-39.

Carvalho-Santos, C., R. Sousa-Silva, J. Gonçalves, and J. P. Honrado. 2016. "Ecosystem Services And Biodiversity Conservation Under Forestation Scenarios: Options To Improve Management In The Vez Watershed, NW Portugal". Regional Environmental Change 16 (6): 1557-1570.

Castro M, Castro JF, Esteves A, Teixeira A, Gómez-Sal A (2000a) Les parcours annuels des troupeaux d'ovins dans la région de montagne de Trás-os-Montes e Alto Douro, au Portugal. In: Guessous F, Rihani N, Ilham A (eds.) Livestock production and climatic uncertainty in the Mediterranean. Wageningen Pers, Wageningen, The Netherlands

Castro M., Castro J., Gómez Sal A., 2010. Relationship between small ruminants behaviour and landscape features in Northeast of Portugal. In Azevedo, João; Feliciano, Manuel; Castro, José;

Castro, J.F. 2004. “Análisis de la evolución reciente del paisaje rural de Trás-os-Montes, Portugal: el caso de los retículos arbóreos en la matriz agrícola”. Tesis Doctoral. Universidad de Alcalá de Henares, Spain

Castro, J.F. 2004. Análisis de la evolución reciente del paisaje rural de Trás-os-Montes, Portugal: el caso de los retículos arbóreos en la matriz agrícola. Diss. Tesis Doctoral. Universidad de Alcalá de Henares, Spain.

Castro, M. 2004. "Análisis de la interacción vegetación-herbivoro en sistemas silvopastorales basados en Quercus pyrenaica." Alcalá de Henares: Universidad de Alcalá de Henares. Tese de Doutoramento

Castro, M. 2008. "A utilização dos pequenos ruminantes na prevenção dos incêndios rurais: estratégia pró-activa de promoção silvopastoril." A silvopastorícia na prevenção dos fogos rurais: 159-175.

Castro, M. 2009. "Silvopastoral systems in Portugal: current status and future prospects." Agroforestry in Europe. Springer, Dordrecht: 111-126.

Castro, M., 2004. Análisis de la Interacción Vegetation-Herbívoro en Sistemas Silvopastorales Basados en *Quercus pyrenaica*. Alcalá de Henares.

Castro, M., A. Ameray, and J. P. Castro. 2020. "A New Approach To Quantify Grazing Pressure Under Mediterranean Pastoral Systems Using GIS And Remote Sensing". International Journal Of Remote Sensing 41 (14): 5371-5387.

Castro, M., and E. F. Nuñez. 2016."Seasonal grazing of goats and sheep on Mediterranean mountain rangelands of northeast Portugal." Livestock Research for Rural Development 28: 1 – 13.

Castro, M., and E. Fernandez-Nuñez. 2014. "Soil Properties And Understory Herbaceous Biomass In Forests Of Three Species Of Quercus In Northeast Portugal". Forest Systems 23 (3): 425 - 437

Castro, M., and J. Castro. 2003. "Ocupação tradicional do território e os novos modelos de utilização do espaço." Pages 13 in V Colóquio Hispano - Português de Estudos Rurais, Bragança.

Castro, M., and J. Castro. 2009. "Novas ferramentas na monitorização de herbívoros em pastoreio.": 36.

Castro, M., E. Fernández-Núñez, and J. Castro. 2015. "Management of grazing circuits in order to promote extensive livestock welfare." World Congress on Integrated Crop-Livestock-Forestry Systems e 3rd International Symposium on Integrated Crop-Livestock Systems (ICLS3).

Castro, M., J. Castro, and . Gómez-Sal. 2004. "The role of black oak woodlands (Quercus pyrenaica Willd.) in small ruminant production in Northeast Portugal." Sustainability of Agrosilvopastoral Systems: 221-229.

Castro, M., J. Castro, and A. Gómez Sal. 2007 "The effect of environmental conditions in the duration of daily grazing itineraties of small ruminants in Northeast Portugal." 6th International Seminar FAO-CHIEAM Network on Sheep and Goats. FAO-CIHEAM.

Cholet, J. et G. Magnon. 2010. Tourbières des montagnes françaises, nouveaux éléments de connaissance, de réflexion et de gestion. Besançon, France : Fédération des conservatoires d’espaces naturels, Pôle-relais tourbières

Craighead, J.R., C. Frank, J. J. Craighead, C. E. Cote, H. K. and Beuchner, 1972. "Satellite and ground radiotracking of elk.". pp 99–111.

Crassous, C. et Karas, F. 2007. Guide de gestion des tourbières et marais alcalins des vallées alluviales de France septentrionale. Pôle-relais tourbières, 2007.

Crassous, Claire, and Floriane Karas. Guide de gestion des tourbières et marais alcalins des vallées alluviales de France septentrionale. Pôle-relais tourbières, 2007.

Daily, G.C., 1997: Nature’s Services: Societal Dependence on Natural Ecosystems. Island Press, Washington D.C., 392 pp.

Debussche, M., G. Debussche, J. Lepart, and G. Debussche. 2001. "Changes In The Vegetation Of Quercus Pubescens Woodland After Cessation Of Coppicing And Grazing". Journal Of Vegetation Science 12 (1): 81 – 92.

DeLaval France. Station d’alimentation FSC40 et FSC400 DeLaval. Sur Internet : (http://www.delavalfrance.fr/-/ProductInformation1/Feeding/Products/Distribution/feeding-stations/DeLaval-feed-stations-FSC40-andFSC400/)Date de dernière consultation : 26/11/2017

Diaz, M.T, S Velasco, V Cañeque, S Lauzurica, F Ruiz de Huidobro, C Pérez, J González, and C Manzanares. 2002. "Use Of Concentrate Or Pasture For Fattening Lambs And Its Effect On Carcass And Meat Quality". Small Ruminant Research 43 (3): 257-268.

Dixon, J.S. 1934. "A Study Of The Life History And Food Habits Of Mule Deer In California". Journal Of Mammalogy 16 (1): 315 – 354.

Doran, C. W. 1943 "Activities and grazing habits of sheep on summer ranges." Journal of Forestry 41.4: 253-258.

Doran-Sheehy, D. M., A. M. Derby, D. Greer, and P. Mongo. 2007. "Habituation Of Western Gorillas: The Process And Factors That Influence It". American Journal Of Primatology 69 (12): 1354-1369.

Eichhorn, M. P., P. Paris, F. Herzog, L. D. Incoll, F. Liagre, K. Mantzanas, and M. Mayus et al. 2006. "Silvoarable Systems In Europe – Past, Present And Future Prospects". Agroforestry Systems 67 (1): 29-50.

Etienne, M. 1996. "Research on temperate and tropical silvopastoral systems: a review."

Étienne, M., B. Hubert, and B. Msika. 1994. "Sylvopastoralisme En Région Méditerranéenne". Revue Forestière Française, no. S: 30 - 41

Feldt, T., and E. Schlecht. 2016. "Analysis Of GPS Trajectories To Assess Spatio-Temporal Differences In Grazing Patterns And Land Use Preferences Of Domestic Livestock In Southwestern Madagascar". Pastoralism 6 (1).

Fernandes, P. M, G. M. Davies, D. Ascoli, C. Fernández, F. Moreira, E. Rigolot, C. Stoof, J. Vega, and D. Molina. 2013. "Prescribed Burning In Southern Europe: Developing Fire Management In A Dynamic Landscape". Frontiers In Ecology And The Environment 11 (s1).

Fernandes, P. M., A. P. Pacheco, R. Almeida, and J. Claro. 2016. "The Role Of Fire-Suppression Force In Limiting The Spread Of Extremely Large Forest Fires In Portugal". European Journal Of Forest Research 135 (2): 253-262.

Ganskopp, D, R Cruz, and D.E. Johnson. 2000. "Least-Effort Pathways?: A GIS Analysis Of Livestock Trails In Rugged Terrain". Applied Animal Behaviour Science 68 (3): 179-190.

Ganteaume, A., A. Camia, M. Jappiot, A. J. San-Miguel, M. Long-Fournel, and C. Lampin. 2013. “A Review of the Main Driving Factors of Forest Fire Ignition over Europe.” Environmental Management 51 (3): 651–662. doi:10.1007/s00267-012-9961-z.

Ganteaume, Anne, Andrea Camia, Marielle Jappiot, Jesus San-Miguel-Ayanz, Marlène Long-Fournel, and Corinne Lampin. 2013. "A Review Of The Main Driving Factors Of Forest Fire Ignition Over Europe". Environmental Management 51 (3): 651-662.

Gómez Sal, A., J. Alvarez, M. A. Muñoz -Yanguas and S. Rebollo. 1993"Patterns of change in the agrarian landscape in an area of the Cantabrian Mountains (Spain)-Assessment by transition probabilities." Landscape ecology and agroecosistems, Lewis, Boca RatoÂn, FL: 141-152.

Gómez-Sal, A. 2000 "The variability of Mediterranean climate as an ecological condition of livestock production systems." Livestock production and climatic uncertainty in the Mediterranean. Wageningen Pers, Wageningen, The Netherlands, pp. 3–11

Gómez-Sal, A. 2000. "Las razas de ganado autóctono en la conservación de la naturaleza." Manual del técnico en medio ambiente natural. Colegio de Veterinarios de Ourense, Ourense, Spain.

Gordon, I.J. 1995. "Animal-Based Techniques For Grazing Ecology Research". Small Ruminant Research 16 (3): 203-214.

Grove, A. T., and O. Rackham. 2001. "The Nature Of Mediterranean Europe: An Ecological History". Yale University Press, New Haven, USA

Haines-Young, R., and M. Potschin-Young. 2018. "Revision Of The Common International Classification For Ecosystem Services (CICES V5.1): A Policy Brief". One Ecosystem 3: e27108.

Hoffmann A., 2018. Améliorer le bien-être animal grâce aux méthodes en élevage de précision. Synthèse bibliographique dans le cadre de la formation Systèmes d’élevage de Montpellier SupAgro, 16 p.

Homburger, H., M. K. Schneider, S. Hilfiker, and A. Lüscher. 2014. "Inferring Behavioral States Of Grazing Livestock From High-Frequency Position Data Alone". Plos ONE 9 (12): e114522.

Hulbert, I. A.R., and J. French. 2001. "The Accuracy Of GPS For Wildlife Telemetry And Habitat Mapping". Journal Of Applied Ecology 38 (4): 869-878.

INMG, 1991. O clima de Portugal. Normas climatológicas da região de "Trás-os-Montes e Alto Douro" e "Beira Interior", correspondentes a 1951 - 1980. INMG, Lisboa : 40 – 180.

Jack, K. M., B. B. Lenz, E. Healan, S. Rudman, V. A.M. Schoof, and L. Fedigan. 2008. "The Effects Of Observer Presence On The Behavior Ofcebus Capucinus In Costa Rica". American Journal Of Primatology 70 (5): 490-494.

Jonsson, H., 2011. Foraging behavior of cattle, sheep and goats on semi-arid pastures in Kenya. Veterinary Medicine thesis. Swedish University of Agricultural Sciences SLU. p.1-19.

Jose, S. 2009. "Agroforestry For Ecosystem Services And Environmental Benefits: An Overview". Agroforestry Systems 76 (1): 1-10.

Kizos, T., T. Plieninger, and H. Schaich. 2013. "“Instead Of 40 Sheep There Are 400”: Traditional Grazing Practices And Landscape Change In Western Lesvos, Greece". Landscape Research 38 (4): 476-498.

LaGroJr, J.A. 2005. "LAND-USE CLASSIFICATION". Encyclopedia Of Soils In The Environment, 321-328.

Landais, E., G. Balent. 1995. "Introduction à l’étude des systèmes d’élevage extensif". Dans : Pratiques d’Élevage Extensif. Identifier, Modéliser Évaluer, Landais, E. (éd.). INRA, Etudes et Recherches sur les Systèmes Agraires et le Développement, (No. 27) : 13-35.

Lawrie, R. 1998. "Technology Of Meat And Meat Products". Meat Science (4th ed.). New York: Pergamon Press.

Lawton, J. H. 1998. "Daily, G. C. (Ed.). 1997. Nature's Services. Societal Dependence On Natural Ecosystems. Island Press, Washington, DC. 392 Pp. ISBN 1-55963-475-8 (Hbk), 1 55963 476 6 (Soft Cover).". Animal Conservation 01 (01): 75-76.

Lecomte, T., C. Le Neveu, L. Nicaise, and E. Valot. 1995. “Gestion écologique par le pâturage: l'expérience des réserves naturelles". Atelier technique des espaces naturels, Montpellier, France

Loehle, C. 2004. "Applying Landscape Principles To Fire Hazard Reduction". Forest Ecology And Management 198 (1-3): 261-267.

Lomba, A., J. Gonçalves, F. Moreira, and J. Honrado. 2013. "Simulating Long-Term Effects Of Abandonment On Plant Diversity In Mediterranean Mountain Farmland". Plant Biosystems - An International Journal Dealing With All Aspects Of Plant Biology 147 (2): 328-342.

Majchrzak, Y. 1992. cEvolution des communautés végétales de marais tourbeux soumises au pâturage de bovins et d'équins. Application pour la gestion conservatrice d'une zone humide, le marais de Lavours" (Ain) (Thèse de doctorat). Université Joseph Fourier Grenoble I, Grenoble, France

Marai, I.F.M., A.A. El-Darawany, A. Fadiel, and M.A.M. Abdel-Hafez. 2007. "Physiological Traits As Affected By Heat Stress In Sheep—A Review". Small Ruminant Research 71 (1-3): 1-12.

Mayes, R.W., and H. Dove. 2000. "Measurement Of Dietary Nutrient Intake In Free-Ranging Mammalian Herbivores". Nutrition Research Reviews 13 (1): 107-138.

McClintock, B. T., R. King, L. Thomas, J. Matthiopoulos, B. J. McConnell, and J. M. Morales. 2012. "A General Discrete-Time Modeling Framework For Animal Movement Using Multistate Random Walks". Ecological Monographs 82 (3): 335-349.

Mech. L. and Barber-Meyer, Shannon. 2002. "A critique of wildlife radio-tracking and its use in national parks". U.S. National Park Service Report: 1-78.

Mech., L. D. 1983. A Handbook Of Animal Radio-tracking. Univ. of Minn. Press, Mpls: 108.

Meuret, M., M. Tichit, N. Hostiou. 2013. Élevage et pâturage « de précision » : l'animal sous surveillance électronique : 13-24

Miguel-Ayanz, A. 2006. Mediterranean European silvopastoral systems. In: Mosquera M.R., Rodríguez A.R., McAdam J. (Eds.), "Silvopastoralism And Sustainable Land Management. (Proceedings Of An International Conference On Silvopastoralism And Sustainable Management Held In Lugo, Spain In April 2004.)

Miguel-Ayanz, A., 2004. Mediterranean European Silvopastoral Systems. International Congress on Silvopastoralism and Sustainable Management. Lugo, NW Spain.

Morales, J. M., D. T. Haydon, J. Frair, K. E. Holsinger, and J. M. Fryxell. 2004. "Extracting more out of relocation data: building movement models as mixtures of random walks". Ecology 85 (9): 2436-2445.

Mosquera-Losada, M. R., E. Fernández-Núñez, and A. Rigueiro-Rodríguez. 2006. "Pasture, Tree And Soil Evolution In Silvopastoral Systems Of Atlantic Europe". Forest Ecology And Management 232 (1-3): 135-145.

Müller, F. 2015. "Le pâturage sur tourbières en Franche-Comté : un mode de gestion favorable à la diversité biologique" Besançon, France.

Murphy, T. A., S. C. Loerch, K. E. McClure, and M. B. Solomon. 1994. "Effects Of Grain Or Pasture Finishing Systems On Carcass Composition And Tissue Accretion Rates Of Lambs". Journal Of Animal Science 72 (12): 3138-3144.

Nair, P.K.R., 1993. An introduction to agroforestry by, Kluwer Academic Publishers in collaboration with International Centre for Research in Agroforestry.

Oliveira, M. I., E. Lamy, M. N. Bugalho, M. Vaz, C. Pinheiro, M. Cancela d'Abreu, F. Capela e Silva, and E. Sales-Baptista. 2013. "Assessing Foraging Strategies Of Herbivores In Mediterranean Oak Woodlands: A Review Of Key Issues And Selected Methodologies". Agroforestry Systems 87 (6): 1421-1437.

Onaindia, M., I. Dominguez, I. Albizu, C. Garbisu, I. Amezaga. 2004. "Vegetation Diversity And Vertical Structure As Indicators Of Forest Disturbance". Forest Ecology And Management. For Ecol Manag 195:341–354

Papanastasis, V. 2004. "Vegetation degradation and land use changes in agrosilvopastoral systems". In: agrosilvopastoral systems. Advances in Geoecology 37: 1-12

Pereira, G.M., B.J. Heins, and M.I. Endres. 2018. "Technical Note: Validation Of An Ear-Tag Accelerometer Sensor To Determine Rumination, Eating, And Activity Behaviors Of Grazing Dairy Cattle". Journal Of Dairy Science 101 (3): 2492-2495.

Pereira, G.M., B.J. Heins, B. O'Brien, A. McDonagh, L. Lidauer, and F. Kickinger. 2020. "Validation Of An Ear Tag–Based Accelerometer System For Detecting Grazing Behavior Of Dairy Cows". Journal Of Dairy Science 103 (4): 3529-3544.

Peri, P. L., F. Dube, and A. C. Varella. 2016. "Silvopastoral systems in the subtropical and temperate zones of South America: an overview." Silvopastoral Systems in Southern South America. Springer, Cham: 1-8.

Pettorelli, N., H. Schulte to Bühne, A. Tulloch, G. Dubois, C. Macinnis-Ng, A. M. Queirós, D. A. Keith, M. Wegmann, F. Schrodt, and M. Stellmes. 2017. "Satellite Remote Sensing

Of Ecosystem Functions: Opportunities, Challenges And Way Forward". Remote Sensing In Ecology And Conservation 4 (2): 71-93.

Reiter, S., G. Sattlecker, L. Lidauer, F. Kickinger, M. Öhlschuster, W. Auer. 2018. "Evaluation of an ear-tag-based accelerometer for monitoring rumination in dairy cows". Journal of dairy science, 101(4): 3398-3411.

Rodgers, A.R. 2001. "Recent telemetry technology: Radio tracking and animal populations", Academic Press, San Diego: 79-121.

Ruiz-Mirazo, J., J, Martínez-Fernández, and C. Vega-García. 2012. "Pastoral Wildfires In The Mediterranean: Understanding Their Linkages To Land Cover Patterns In Managed Landscapes". Journal Of Environmental Management 98: 43-50.

Scheibe, K. M., K. Eichhorn, M. Wiesmayr, B. Schonert, and O. Krone. 2008. "Long-Term Automatic Video Recording As A Tool For Analysing The Time Patterns Of Utilisation Of Predefined Locations By Wild Animals". European Journal Of Wildlife Research 54 (1): 53-59.

Schlecht, E., U. Dickhoefer, E. Gumpertsberger, and A. Buerkert. 2009. "Grazing Itineraries And Forage Selection Of Goats In The Al Jabal Al Akhdar Mountain Range Of Northern Oman". Journal Of Arid Environments 73 (3): 355-363.

Schweinzer, V., D. Klein-Jöbstl, M. Drillich, and M. Iwersen. 2018. "Evaluation Of An Ear-Tag-Based Accelerometer For Monitoring Rumination In Dairy Cows". Journal Of Dairy Science 101 (4): 3398-3411. doi:10.3168/jds.2017-12686.

Swain, D. L., M. A. Friend, G. J. Bishop-Hurley, R. N. Handcock, and T. Wark. 2011. "Tracking Livestock Using Global Positioning Systems - Are We Still Lost?". Animal Production Science 51 (3): 167.

Thuiller, W., S. Lavorel, M. B. Araujo, M. T. Sykes, and I. C. Prentice. 2005. "Climate Change Threats To Plant Diversity In Europe". Proceedings Of The National Academy Of Sciences 102 (23): 8245-8250.

Tomkiewicz, S. M., M. R. Fuller, J. G. Kie, and K. K. Bates. 2010. "Global Positioning System And Associated Technologies In Animal Behaviour And Ecological Research". Philosophical Transactions Of The Royal Society B: Biological Sciences 365 (1550): 2163-2176.

Tomkins, N., and P. O'Reagain. 2007. "Global Positioning Systems Indicate Landscape Preferences Of Cattle In The Subtropical Savannas". The Rangeland Journal 29 (2): 217 – 222.

Torres-Manso, F., P. Fernandes, R. Pinto, H. Botelho, and A. Monzon. 2014. "Regional Livestock Grazing, Human Demography And Fire Incidence In The Portuguese Landscape". Forest Systems 23 (1): 15.

Turner, L.W., M.C. Udal, B. T. Larson, and S.A. Shearer. 2000. "Monitoring Cattle Behavior And Pasture Use With GPS And GIS". Canadian Journal Of Animal Science 80 (3): 405-413.

Ungar, E. D., Z. Henkin, M. Gutman, A. Dolev, A. Genizi, and D. Ganskopp. 2005. "Inference Of Animal Activity From GPS Collar Data On Free-Ranging Cattle". Rangeland Ecology & Management 58 (3): 256-266.

Vallentine, J. F. 2001. Grazing Management. Second ed. Academic Press, San Diego, CA

Werner, J., L. Leso, C. Umstatter, J. Niederhauser, and E. Kennedy. 2018. "Evaluation Of The Rumiwatchsystem For Measuring Grazing Behaviour Of Cows". Journal Of Neuroscience Methods 300: 138-146.

Williams, R. E. 1954. "Modern Methods of Getting Uniform Use Of Ranges". Journal Of Range Management 7 (2): 77.

Williamson, E.A. and A.T.C. Feistner. 2003. "Habituating primates: processes, techniques, variables and ethics.": 25-39.

# 8. Annexes

Annex 1: Result obtained in excel file from DOMODIS user interface, after coping the txt data

| Dispositivo | Latitud | Longitud | Fecha | Tempo | Bateria | Year | Month | Day | Hour | Minutes |
|---|---|---|---|---|---|---|---|---|---|---|
| Marina_1 | 41.54425 | -7.04892 | 06/12/2019 | 01:13:25 | LOW | 2019 | 12 | 6 | 1 | 13 |
| Marina_3 | 41.54446 | -7.04907 | 06/12/2019 | 02:13:33 | LOW | 2019 | 12 | 6 | 2 | 13 |
| Marina_2 | 41.54421 | -7.04874 | 06/12/2019 | 02:58:45 | LOW | 2019 | 12 | 6 | 2 | 58 |
| Marina_2 | 41.54419 | -7.04886 | 06/12/2019 | 03:01:58 | LOW | 2019 | 12 | 6 | 3 | 1 |
| Marina_2 | 41.54427 | -7.04892 | 06/12/2019 | 03:19:38 | LOW | 2019 | 12 | 6 | 3 | 19 |
| Marina_1 | 41.54419 | -7.04855 | 06/12/2019 | 03:32:48 | LOW | 2019 | 12 | 6 | 3 | 32 |
| Marina_3 | 41.54374 | -7.04868 | 06/12/2019 | 04:07:01 | LOW | 2019 | 12 | 6 | 4 | 7 |
| Marina_1 | 41.54425 | -7.04878 | 06/12/2019 | 04:59:23 | LOW | 2019 | 12 | 6 | 4 | 59 |
| Marina_1 | 41.54425 | -7.04869 | 06/12/2019 | 05:04:23 | LOW | 2019 | 12 | 6 | 5 | 4 |
| Marina_1 | 41.54434 | -7.04886 | 06/12/2019 | 05:09:23 | LOW | 2019 | 12 | 6 | 5 | 9 |
| Marina_2 | 41.54425 | -7.04892 | 06/12/2019 | 05:32:50 | LOW | 2019 | 12 | 6 | 5 | 32 |
| Marina_3 | 41.54416 | -7.04855 | 06/12/2019 | 06:17:17 | LOW | 2019 | 12 | 6 | 6 | 17 |
| Marina_3 | 41.54412 | -7.04849 | 06/12/2019 | 06:26:56 | LOW | 2019 | 12 | 6 | 6 | 26 |
| Marina_3 | 41.54412 | -7.0484 | 06/12/2019 | 06:31:55 | LOW | 2019 | 12 | 6 | 6 | 31 |
| Marina_1 | 41.54398 | -7.04916 | 06/12/2019 | 07:03:08 | LOW | 2019 | 12 | 6 | 7 | 3 |
| Marina_3 | 41.54414 | -7.04858 | 06/12/2019 | 07:54:54 | LOW | 2019 | 12 | 6 | 7 | 54 |
| Marina_2 | 41.54416 | -7.04871 | 06/12/2019 | 08:41:59 | LOW | 2019 | 12 | 6 | 8 | 41 |
| Marina_1 | 41.54414 | -7.04868 | 06/12/2019 | 08:48:07 | LOW | 2019 | 12 | 6 | 8 | 48 |
| Marina_3 | 41.54416 | -7.04855 | 06/12/2019 | 08:50:49 | LOW | 2019 | 12 | 6 | 8 | 50 |
| Marina_1 | 41.54417 | -7.04886 | 06/12/2019 | 09:03:06 | LOW | 2019 | 12 | 6 | 9 | 3 |
| Marina_3 | 41.54427 | -7.04876 | 06/12/2019 | 09:08:31 | LOW | 2019 | 12 | 6 | 9 | 8 |
| Marina_3 | 41.54423 | -7.04867 | 06/12/2019 | 09:13:31 | LOW | 2019 | 12 | 6 | 9 | 13 |
| Marina_3 | 41.54423 | -7.04858 | 06/12/2019 | 09:18:31 | LOW | 2019 | 12 | 6 | 9 | 18 |
| Marina_1 | 41.54408 | -7.04875 | 06/12/2019 | 09:21:45 | LOW | 2019 | 12 | 6 | 9 | 21 |
| Marina_3 | 41.5442 | -7.04872 | 06/12/2019 | 09:23:31 | LOW | 2019 | 12 | 6 | 9 | 23 |
| Marina_1 | 41.54411 | -7.04883 | 06/12/2019 | 09:26:48 | LOW | 2019 | 12 | 6 | 9 | 26 |
| Marina_3 | 41.54407 | -7.04855 | 06/12/2019 | 09:28:31 | LOW | 2019 | 12 | 6 | 9 | 28 |

Annex 2: Nomenclature of the COS2018's Land use occupation obtained from DGT

dgTerritório

**Nomenclatura da Carta de Uso e Ocupação do Solo de Portugal Continental**

| COS2018 | | | |
|---|---|---|---|
| **Nível 1** | **Nível 2** | **Nível 3** | **Nível 4** |
| 1.Territórios artificializados | 1.1 Tecido edificado | 1.1.1 Tecido edificado contínuo | 1.1.1.1 Tecido edificado contínuo predominantemente vertical |
| | | | 1.1.1.2 Tecido edificado contínuo predominantemente horizontal |
| | | 1.1.2 Tecido edificado descontínuo | 1.1.2.1 Tecido edificado descontínuo |
| | | | 1.1.2.2 Tecido edificado descontínuo esparso |
| | | 1.1.3 Espaços vazios em tecido edificado | 1.1.3.1 Áreas de estacionamentos e logradouros |
| | | | 1.1.3.2 Espaços vazios sem construção |
| | 1.2 Indústria, comércio e instalações agrícolas | 1.2.1 Indústria | 1.2.1.1 Indústria |
| | | 1.2.2 Comércio | 1.2.2.1 Comércio |
| | | 1.2.3 Instalações agrícolas | 1.2.3.1 Instalações agrícolas |
| | 1.3 Infraestruturas | 1.3.1 Infraestruturas de produção de energia | 1.3.1.1 Infraestruturas de produção de energia renovável |
| | | | 1.3.1.2 Infraestruturas de produção de energia não renovável |
| | | 1.3.2 Infraestruturas de águas e tratamento de resíduos | 1.3.2.1 Infraestruturas para captação, tratamento e abastecimento de águas para consumo |
| | | | 1.3.2.2 Infraestruturas de tratamento de resíduos e águas residuais |
| | 1.4 Transportes | 1.4.1 Redes viárias e ferroviárias e espaços associados | 1.4.1.1 Rede viária e espaços associados |
| | | | 1.4.1.2 Rede ferroviária e espaços associados |
| | | 1.4.2 Áreas portuárias | 1.4.2.1 Terminais portuários de mar e de rio |
| | | | 1.4.2.2 Estaleiros navais e docas secas |
| | | | 1.4.2.3 Marinas e docas pesca |
| | | 1.4.3 Aeroportos e aeródromos | 1.4.3.1 Aeroportos |
| | | | 1.4.3.2 Aeródromos |
| | 1.5 Áreas de extração de inertes, áreas de deposição de resíduos e estaleiros de construção | 1.5.1 Áreas de extração de inertes | 1.5.1.1 Minas a céu aberto |
| | | | 1.5.1.2 Pedreiras |
| | | 1.5.2 Áreas de deposição de resíduos | 1.5.2.1 Aterros |
| | | | 1.5.2.2 Lixeiras e Sucatas |
| | | 1.5.3 Áreas em construção | 1.5.3.1 Áreas em construção |
| | 1.6 Equipamentos | 1.6.1 Equipamentos desportivos | 1.6.1.1 Campos de golfe |
| | | | 1.6.1.2 Instalações desportivas |
| | | 1.6.2 Equipamentos de lazer e parques de campismo | 1.6.2.1 Parques de campismo |
| | | | 1.6.2.2 Equipamentos de lazer |
| | | 1.6.3 Equipamentos culturais | 1.6.3.1 Equipamentos culturais |
| | | 1.6.4 Cemitérios | 1.6.4.1 Cemitérios |
| | | 1.6.5 Outros equipamentos e instalações turísticas | 1.6.5.1 Outros equipamentos e instalações turísticas |
| | 1.7 Parques e jardins | 1.7.1 Parques e jardins | 1.7.1.1 Parques e jardins |
| 2.Agricultura | 2.1 Culturas temporárias | 2.1.1 Culturas temporárias de sequeiro e regadio e arrozais | 2.1.1.1 Culturas temporárias de sequeiro e regadio |
| | | | 2.1.1.2 Arrozais |
| | 2.2 Culturas permanentes | 2.2.1 Vinhas | 2.2.1.1 Vinhas |
| | | 2.2.2 Pomares | 2.2.2.1 Pomares |
| | | 2.2.3 Olivais | 2.2.3.1 Olivais |
| | 2.3 Áreas agrícolas heterogéneas | 2.3.1 Culturas temporárias e/ou pastagens melhoradas associadas a culturas permanentes | 2.3.1.1 Culturas temporárias e/ou pastagens melhoradas associadas a vinha |
| | | | 2.3.1.2 Culturas temporárias e/ou pastagens melhoradas associadas a pomar |
| | | | 2.3.1.3 Culturas temporárias e/ou pastagens melhoradas associadas a olival |
| | | 2.3.2 Mosaicos culturais e parcelares complexos | 2.3.2.1 Mosaicos culturais e parcelares complexos |
| | | 2.3.3 Agricultura com espaços naturais e seminaturais | 2.3.3.1 Agricultura com espaços naturais e seminaturais |
| | 2.4 Agricultura protegida e viveiros | 2.4.1 Agricultura protegida e viveiros | 2.4.1.1 Agricultura protegida e viveiros |
| 3.Pastagens | 3.1 Pastagens | 3.1.1 Pastagens melhoradas | 3.1.1.1 Pastagens melhoradas |
| | | 3.1.2 Pastagens espontâneas | 3.1.2.1 Pastagens espontâneas |
| 4.Superfícies agroflorestais (SAF) | 4.1 Superfícies agroflorestais (SAF) | 4.1.1 Superfícies agroflorestais (SAF) | 4.1.1.1 SAF de sobreiro |
| | | | 4.1.1.2 SAF de azinheira |
| | | | 4.1.1.3 SAF de outros carvalhos |
| | | | 4.1.1.4 SAF de pinheiro manso |
| | | | 4.1.1.5 SAF de outras espécies |
| | | | 4.1.1.6 SAF de sobreiro com azinheira |
| | | | 4.1.1.7 SAF de outras misturas |
| 5.Florestas | 5.1 Florestas | 5.1.1 Florestas de folhosas | 5.1.1.1 Florestas de sobreiro |
| | | | 5.1.1.2 Florestas de azinheira |
| | | | 5.1.1.3 Florestas de outros carvalhos |
| | | | 5.1.1.4 Florestas de castanheiro |
| | | | 5.1.1.5 Florestas de eucalipto |
| | | | 5.1.1.6 Florestas de espécies invasoras |
| | | | 5.1.1.7 Florestas de outras folhosas |
| | | 5.1.2 Florestas de resinosas | 5.1.2.1 Florestas de pinheiro bravo |
| | | | 5.1.2.2 Florestas de pinheiro manso |
| | | | 5.1.2.3 Florestas de outras resinosas |
| 6.Matos | 6.1 Matos | 6.1.1 Matos | 6.1.1.1 Matos |
| 7. Espaços descobertos ou com pouca vegetação | 7.1 Espaços descobertos ou com pouca vegetação | 7.1.1 Praias, dunas e areais | 7.1.1.1 Praias, dunas e areais interiores |
| | | | 7.1.1.2 Praias, dunas e areais costeiros |
| | | 7.1.2 Rocha nua | 7.1.2.1 Rocha nua |
| | | 7.1.3 Vegetação esparsa | 7.1.3.1 Vegetação esparsa |
| 8.Zonas húmidas | 8.1 Zonas húmidas | 8.1.1 Zonas húmidas interiores | 8.1.1.1 Pauis |
| | | 8.1.2 Zonas húmidas litorais | 8.1.2.1 Sapais |
| | | | 8.1.2.2 Zonas entremarés |
| 9.Massas de água superficiais | 9.1 Massas de água interiores | 9.1.1 Cursos de água | 9.1.1.1 Cursos de água naturais |
| | | | 9.1.1.2 Cursos de água modificados ou artificializados |
| | | 9.1.2 Planos de água | 9.1.2.1 Lagos e lagoas interiores artificiais |
| | | | 9.1.2.2 Lagos e lagoas interiores naturais |
| | | | 9.1.2.3 Albufeiras de barragens |
| | | | 9.1.2.4 Albufeiras de represas ou de açudes |
| | | | 9.1.2.5 Charcas |
| | 9.2 Aquicultura | 9.2.1 Aquicultura | 9.2.1.1 Aquicultura |
| | 9.3 Massas de água de transição e costeiras | 9.3.1 Salinas | 9.3.1.1 Salinas |
| | | 9.3.2 Lagoas costeiras | 9.3.2.1 Lagoas costeiras |
| | | 9.3.3 Desembocaduras fluviais | 9.3.3.1 Desembocaduras fluviais |
| | | 9.3.4 Oceano | 9.3.4.1 Oceano |