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Spatial Modelling of Grazing Pressure by Small Ruminants in Bragança Region

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Abstract

Extensive grazing systems are characterised by low stocking densities, with positive impacts on the landscape, promoting diversity and heterogeneity. In order to manage this type of systems, we have implemented a robust tool which is the evaluation of the grazing pressure. This latter can establish the relationship between the ruminant and the pasture. This study is made in Bragança region, situated in the northeast part of Portugal. We used available databases such as: land use and cover (LUC) map of Portugal (COS2018), parishes' administrative boundaries (CAOP2012) and sheep and goats' locations and headcounts of the study area (OTSA). We define eight LUC classes: permanent crops (PC), annual crops (AC), grasslands (G), shrublands (S), grazed (GF) and ungrazed forests (UF), urban (U) and water bodies (W). The stocking densities and the distribution of the grazing pressure over the LUC classes was done by GIS geoprocessing techniques involving multiple ring buffer zones, data overlapping and spatial interpolation. We used two different methods for spatial interpolation of stocking densities; the weighted inverse distance (IDW) and the ordinary kriging (OK), with better results for the latter, with average prediction errors of 0.0003. Overlapping the grazing areas of the LUC map and the stocking densities, it allows us to obtain the grazing pressure (GP). The most common GP in Bragança is about 1-1.5 sheep or goats/ha. The LUC class with the highest grazing pressure is annual crops (2.22 sheep or goat/ha), the less grazed class is shrublands (1.42 sheep or goat/ha). Regarding the availability of LUC, shrublands have the highest coverage in Bragança region (26.8%), followed by PC (20.5%), GF (18.5%), AC (15.7%), UF (9.2%), G (5.5%), U (3.1%) and W (0.7%). The herds in the study area are globally composed of 11.42% goats and 88.58% sheep. The grazing pressure is related to the food preferences of each species and has been taken into account in this assessment in order to increase the accuracy of the results obtained.

Key words: Grazing pressure, GIS, Extensive livestock system, Stocking density, Land-use cover, Grazing management, Spatial interpolation.

Resumo

Os sistemas de pastoreio extensivos caracterizam-se por baixos encabeçamentos, com impactos positivos sobre a paisagem, promovendo a diversidade e a heterogeneidade. A fim de gerir este tipo de sistemas, implementámos uma ferramenta robusta que é a avaliação da pressão de pastoreio. Este último pode estabelecer a relação entre o ruminante e o pasto. Este estudo é realizado na região de Bragança, situada na parte nordeste de Portugal. Utilizámos bases de dados disponíveis, tais como: mapa de uso e cobertura do solo (LUC) de Portugal (COS2018), limites administrativos das freguesias (CAOP2012) e localizações e efectivos pecuários de ovinos e caprinos da área de estudo (OTSA). Definimos oito classes de LUC: culturas permanentes (PC), culturas anuais (AC), prados (G), matos (S), florestas pastoreadas (GF) e florestas não pastoreadas (UF), áreas urbanas (U) e massas de água (W). As densidades de pastoreio e a distribuição da pressão de pastoreio sobre as classes LUC foram feitas por técnicas de geoprocessamento GIS envolvendo "multiple ring buffer zones", sobreposição de dados e interpolação espacial. Utilizámos dois métodos diferentes para a interpolação espacial das densidades de pastoreio; a distância inversa ponderada (IDW) e o kriging normal (OK), com melhores resultados para este último, com erros de predição médios de 0,0003. Sobrepondo as áreas de pastagem do mapa LUC e as densidades de pastoreio, permite-nos obter a pressão de pastoreio (GP). O GP mais comum em Bragança é cerca de 1-1,5 ovelhas ou cabras/ha. A classe LUC com maior pressão de pastoreio é a de culturas anuais (2,22 ovelhas ou cabras/ha), a classe menos pastoreada é a de matos (1,42 ovelhas ou cabras/ha). Relativamente à disponibilidade do LUC, os matos têm a maior cobertura na região de Bragança (26,8%), seguidos pelo PC (20,5%), GF (18,5%), AC (15,7%), UF (9,2%), G (5,5%), U (3,1%) e W (0,7%). Os rebanhos na área de estudo são compostos globalmente por 11,42% de caprinos e 88,58% de ovinos. A pressão de pastoreio está relacionada com as preferências alimentares de cada espécie e foi tomada em consideração nesta avaliação a fim de aumentar a exactidão dos resultados obtidos.

Palavras-chave: Pressão de pastoreio, SIG, Sistema extensivo de pecuária, Densidade de pastoreio, Uso e Ocupação do Solo, Gestão do pastoreio, Interpolação espacial.

Table of contents

List of figures

List of tables

List of equations

List of Annexes

Symbols list

AC : Annual crops

ASE : Average standard error

CAOP : Carta Administrativa Oficial de Portugal

COS : Carta de Uso e Ocupação do Solo

G : Grasslands

GF : Grazed forests

GIS : Geographic information system

GP : Grazing pressure

IDW : Inverse distance weighted

LSU : Livestock units

LUC : Land use and cover

ME : Mean error

MS : Mean standardized

Nb : Number

NNE : Nearest neighbour expected

NNO : Nearest neighbour observed

OTSA : Observatório Transfronteiriço de Sanidade Animal

PC : Permanent crops

PDO : Protected Designation of Origin

PGI : Protected Geographical Indication

RMS : Root mean square

RMSS : Root mean square standardized

S : Shrublands

SD : Stocking density

U : Urban

UAA : Utilized agricultural area

UF : Ungrazed forests

W : Water bodies

1 Introduction

Pastoral systems provide an opportunity to manage the fuel loads and reduce fire risk in the Mediterranean ecosystems (Castro et al., 2020). Portugal, like other European countries, is prone to wildfires, and this phenomenon is increasing with climate change, therefore it needs a rational forest management, maybe the only way to reduce the intense fire-fighting interventions that have occurred in recent years (Silva et al., 2019). Extensive livestock could be used as an instrument to reduce wildfire hazards because grazing has an effect on reduction of fuels (Larson, 2019).

Extensive livestock production are characterised by low productivity per animal and area, extensive livestock systems generally have a low stocking density and are based mainly on spontaneous resources, permanent pasture and by products of agriculture (Blench, 1999). Seasonally, livestock grazing on fallows and stubbles of cereals, classified on the land use maps as annual crops (Brouwer & Crabtree, 1999). Permanent crops such us chestnut and olive grows are also used by livestock, reducing biomass accumulation(Evans & Finkral, 2009).

The biomass management changes fuel conditions through the removal of forest biomass, it can potentially contribute to fuel reduction and ecosystem restoration (USDA Forest Service et al., 2005). Extensive livestock production contributes to the reduction of the fuel load and promotes the reduction of the risk of fire (Ruiz-Mirazo et al., 2012). However, while cattle grazing mainly reduces the amount of fine herbaceous fuels, goat and sheep grazing can also reduce the shrub component (Larson, 2019).

Furthermore, the current abundance of wildfires in Mediterranean landscapes is considered a direct consequence of land-use change (Ruiz-Mirazo et al., 2012), therefore it would be essential to know the components of the landscape and the spatial distribution of herds, assuming that one of the factors involved in landscape change could be grazing, and also the preferences of the ruminants for each class of land-use.

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.

Based on the principle that grazing can contribute to reduction of fire risk, by the consumption and trampling of vegetation, it is essential to know the animal grazing pressure on each vegetation class of land use and cover across the territory. But, it depends also in the preferences of the animals for each one.

We have established as principal objectives of this work to contribute to the increase of knowledge about the function of extensive grazing with small ruminants in the region of Bragança.

The main steps to achieve the objectives are:

- The reclassification of land use and land cover (LUC) of COS2018 according to the grazing habits of small ruminants in the study area;
- The analysis of the spatial distribution of herds and their number of heads in the study area for stocking density assessment;
- The spatial distribution of stocking density by LUC classes according to available area and grazing preferences for the assessment of grazing pressure;
- Discussion on the function of extensive grazing with small ruminants to shape the landscape and reduce the risks and severity of wildfires in the Bragança region.

2 State of art

2.1 Sheep and goat heads in Portugal

Sheep and goats grazing in the countryside are part of the landscape and cultural heritage of many European countries (*EPRS*, 2017), Portugal is counted amongst the European countries with the highest goat flock density in 2013. By consulting statistical data and official EU reports on animal production, we find various ways of presenting the data. For example, by expressing livestock in number of head (number of animals), when talking about animals of the same species. According to the *GPP (2016)*, in Portugal there were 373,000 goats and 2,043,000 sheep in 2015, while in 2014 there were 382,000 and 2,033,000 respectively.

However, when comparing and aggregating animal numbers of different species or categories, taking into account animal species, age, live weight and production vocation, in relation to food requirements and animal effluent production, the "livestock unit (LSU)" is used as a standard unit of equivalence (*DL 81/2013*) (*Portaria n.º 338-A/2016*).

The livestock density, can also be used, i.e. the livestock units per hectare of utilised agricultural area (LSU/ha UAA). For information, in 2016, Portugal had 0.6 LSU/ha UAA with a 9.3% increase in livestock density from 2013 to 2016 (*EUROSTAT*, 2019) (Figure 1).

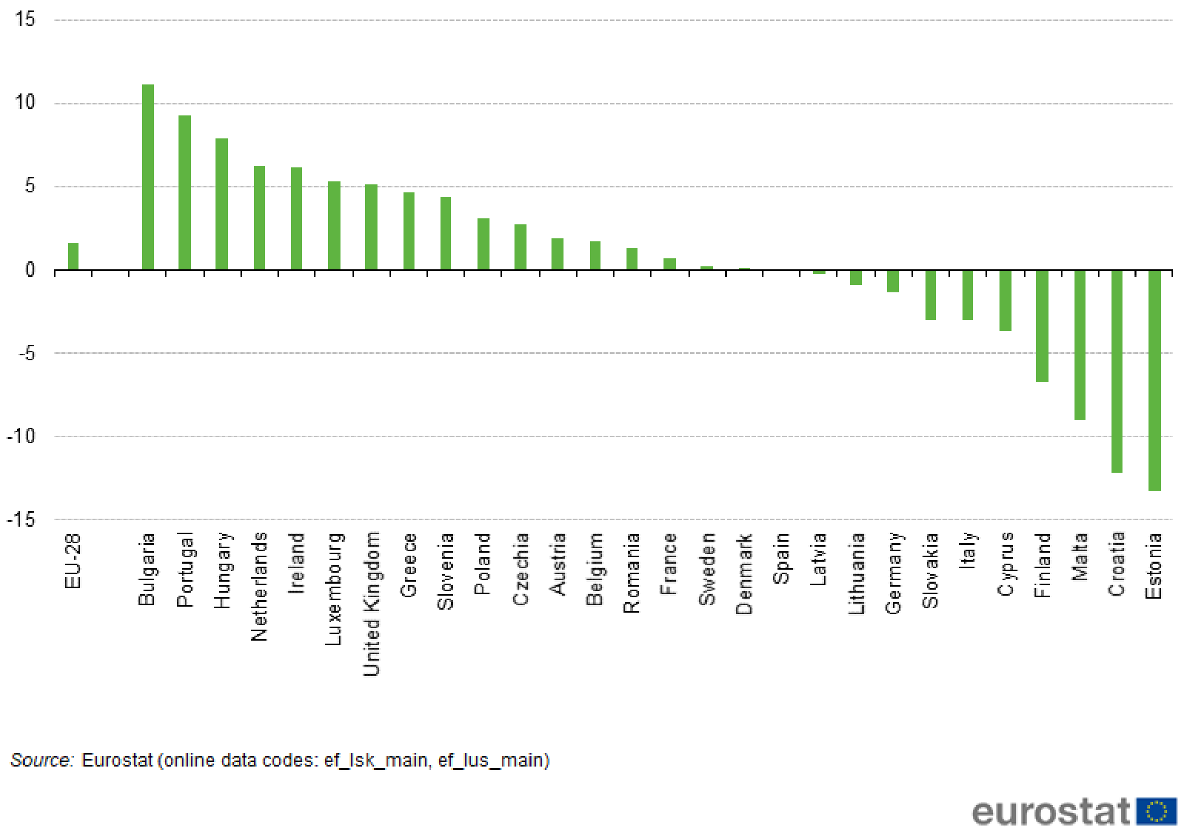

Figure 1: Change in livestock density from 2013 to 2016 in the European states (%)

In 2000, Portugal registered 2.5 million LSU (0.25 LSU per inhabitant) while in 2010 it registered 2.2 million LSU (0.21 LSU per inhabitant). Although there was a reduction of 14% overall, cattle remained constant in the period 2000-2010 (*INE*, 2009).

In the regional context, and considering the importance of sheep and goat grazing, both in the usable agricultural area and in silvopastoral and forestry systems, it makes sense to consider stocking density (SD) (number of animals/ha), which is a measure of global livestock density that can be spatially interpolated in a GIS environment (Bryssinckx et al., 2012). Stocking density can be defined as the relationship between the number of animals and the specific unit of land being grazed at any one time (Jr & Aiken, 2019); it is an instantaneous measurement of the animal-to-land area relationship (Longland, 2013). This notion is different from stocking rate which reflects the relationship between the number of animals and the total area of the land in one or more units utilized over a specified time (Allen et al., 2011).

Stocking density is closely related to grazing pressure, which is an important controlling factor for the vegetation. Low stocking densities create a diverse habitat for many species (Klink et al., 2020).

The distribution of stocking density by land use and cover (LUC) is the grazing pressure (GP) (number of animals/ha LUC) which can be obtained by geoprocessing in GIS by overlaying stocking density with land use and cover mapping.

Grazing pressure can be defined as the relationship between animal live weight and forage mass per unit area of the specific unit of land being grazed at any one time; an instantaneous measurement of the animal-to-forage relationship (Mott, 1973; quoted by Bransby,1977). More recently, grazing pressure is based on the demand for feed from herbivores and detritivores within an environment compared to the amount available for consumption (Baytekin et al., 2012). This could come from domestic animals, such as goats and cattle; feral animals and wild animals. Total grazing pressure is the ratio of the demand for forage and the supply of forage available (*Business Queensland*, 2016). Demand can come from both livestock and native or feral animals. Grassland ecosystems in particular have evolved in the presence of grazing from large herbivores and are well-adapted to it (D.G et al., 1988).

2.2 Extensive livestock systems

Agricultural practices have changed in recent decades, with a concomitant change in land use and cover (Casasús et al., 2012). a negative relationship between adoption of more intensive farming practices, namely reproductive and feeding management, and the use of natural pastures. Additionally, intensification was frequent in farms owned by younger and more innovative farmers, while more traditional farms with extensive pasture use had the lowest continuity; although extensive livestock system have good effects on the landscape scale (Allen et al., 2011).

Extensive grazing systems are normally associated with the constant demand for intrinsic regulations, e.g. low consumption of agronomic and/or veterinary inputs, use of native and rustic breeds, and use of trees and shrub species as fodder for animals, among others (Castro 2016). Moreover, these systems occupy another role as they are considered as an integral part of the territory’s history and cultural heritage (Gama., 2004; quoted by Torres-Manso et al., 2017). They also illustrate the ‘One Health’ concept: the health of the soil, animals, and consumers are all interdependent (Horsin et al., 2019).

According to the definition given by Beaufoy et al, (1994), low intensity farming systems are distinct from intensive farming systems especially in that they are low in their use of external inputs, especially fertilizers and agrochemicals, and that what’s make them resilient (Torres-Manso et al., 2017). Extensive farming is a similar term but is applied particularly to those farming systems, which on top of a limited use of external inputs, are characterized by the exploitation of land on a large scale (Beaufoy et al., 1994).

To be viable, extensive livestock production systems need to reduce their charges and to stand out with a high additional value for their products: European quality labels e.g. PDO (Protected Designation of Origin) and PGI (Protected Geographical Indication), in addition to direct selling for example, and use hardy breeds adapted to the local specificities (Horsin et al., 2019). Through these quality systems, the European commission defines specifications (*Réglement d'exécution de la commission*, 2012) and grants tools to increase the visibility of the products of native species (sheep and goats) and, consequently, to increase their chances of success on the market. (*Parlement européen,* 2018)

In the region of Bragança, two breeds of goats are exploited with entitlement to European Community aid by annual direct payment and payments with 5-year commitments (*ANCRAS*, 2020). They are the "Cabra Preta do Montesinho", almost exclusively in the northern region of Bragança, with 1,584 animals on 36 farms, and the "Cabra Serrana Transmontana". Both breeds are highly prized for the excellent quality of the kid meat. The black goat is raised almost exclusively in the northern region of Bragança. The "Cabra Serrana Transmontana" is widely spread throughout Portugal, with 15,190 animals on 195 farms.

There are several breeds of sheep in the region, with different aptitudes: sheep exploited for meat and for meat and milk production. Sheep exploited for meat in 2020 are as follows: the "Churra Badana", with 3,074 animals on 32 farms, the "Churra Galega Mirandesa", with 5,408 animals on 69 farms, the "Churra Galega Bragançana Preta", with 3,285 animals on 45 farms, the "Churra Galega Bragançana Branca", with 12,878 animals on 124 farms. The "Churra da Terra Quente", with 14,620 animals on 131 farms in 2020, with two certified products, "Terrincho" Cheese and "Terrincho" Lamb (ANIDOP, 2020) (*SPREGA*, 2020) (*ANCOTEQ*, 2020). For breeds classified as indigenous and threatened with extinction, breeders receive, in addition to premiums and aid granted to most sheep, additional aid to encourage the continued exploitation of this breed.

In the north of Portugal, most of the production of small ruminant is an extensive activity based on the daily movements of livestock around their villages (Castro et al., 2004). According to the same author, in this shepherding system, the flocks walk between 3 and 8 km, always led by a shepherd. Based on that, herds have a variable itinerary and each location can be grazed by different herds of the same parish on the same day or on different days (Schlecht et al., 2006).

Herd movements should be understood within the larger context of the annual transhumance in which itinerant pastoralists move to different pasture zones within and between seasons. For example, when there are no longer good pastures within the radius of the distance that a herd can travel in one day, mobile pastoralists move to different pastures (Moritz et al., 2010).

2.3 Effects of grazing on the landscape

The grazing animals has shaped the landscape for millennia. In situations of strong aridity, such as in the sub-saharan border, overgrazing can occur (Fikri Benbrahim et al., 2004). If on the one hand overgrazing can lead to land degradation and loss of biodiversity, undergrazing can induce the succession of pastures to scrubland with subsequent loss of pasture habitat (Barcella et al., 2016). Livestock grazing control the dominancy of certain species and favours the less-competitive ones, increasing biodiversity and reinforcing structural heterogeneity through selective defoliation, trampling, nutrient cycling and seed dispersal (Rook & Tallowin, 2003). In the other hand, plant species richness benefits from higher stocking densities as grazing opens the canopy and decreases light competition (Klink et al., 2020).

Grazing can also be a useful tool against shrub encroachment, helping in the maintenance of the open structure of Mediterranean wood pastures (Casasús et al., 2012). Aharoni et al. (2000) has pointed out that grazing contributes not only in supporting animal production but also in maintaining an open woodland structure, reduces biomass and the risk of fire**,** increases species diversity (Perevolotsky and Seligman, 1998) and facilitates recreational use of the landscape (Henkin, 2011)**.**

In former times, large ruminants were a natural component of the ecosystem. Most present day open habitats have been created and maintained by grazing (Bignal, 1996). In addition, one important determinant of how grazing affects the vegetation is the spatial pattern of pasture use (Güsewell et al., 2007).

Torres-Manso et al. (2017) has documented that grazing helps store atmospheric carbon and mitigates climate change. In the same context, the interaction of temperature, rainfall and sunlight has a direct effect on pasture growth (Louhaichi et al., 2019). Pastures grow well during warmer months provided there is enough moisture unlike winter where growth is minimal; however, forbs can be abundant, providing extra pasture quantity and protein for grazing livestock (Hamilton et al., 2009).

Climate conditions have an important role in identifying itineraries grazed by ruminants, for instance in high temperatures during summer, sheep and goats avoid grazing in this harsh conditions, so they are shepherded to graze during the night (Torres-Manso et al., 2017).

The incidence of forest fires in Portugal is high compared to other Mediterranean European countries and the increase and severity of fires in recent decades has been worsened by complex interactions between land use, livestock grazing and human population (Torres-Manso et al., 2014).

The knowledge on causal factors driving large wildfires can be used for strategies to combat them, for instance socio-economic factors (e.g. ageing rural populace, and forest and agricultural policies) and changes in land use and cover (e.g. agricultural abandonment, expansion of highly flammable species such as *Pinus pinaster* and *Eucalyptus globulus L.*, homogenization of the landscape) (Pausas, 2004). For that, we can proceed to implement fire-fuel managed and more resilient landscapes instead of suppressing small and medium size fires which can lead to have landscapes with higher flammability thus more severe forest fires (Rodrigues et al., 2020).

At the national level, 35% of the municipalities in Portugal showed a positive trend (increase) of area burned and 5% revealed negative trends for the period 1980-2014 (Silva et al., 2019).

The annual area burned and the fire regime in Portugal are mainly related to vegetation characteristics (fuel loads types and accumulated biomass), but also to meteorological characteristics (Sharples, 2009).

There are specific land use and cover classes which are more prone to wildfires than others, for example, forest and shrub lands. However, Ferreira-Leite et al. (2016) mentions that areas characterized by herbaceous plant and shrubs, are extremely susceptible to fire because of their low moisture content and flammable fuel load in dry and hot seasons. Fire recurrence cycle is enlarged if shrub biomass is grazed by goats (Torres-Manso et al., 2017).

Rural exodus is one of the causes of the increase in forest fires; it leads to the accumulation of biomass over the years and therefore can feed catastrophic fires during the summer months (Beverly &Martell, 2005).

The proportion of uncultivated land, due to the rural exodus since the 1950s, was the most important factor affecting burnt areas in Portugal, where this uncultivated land were mostly covered by shrubs, grass and other light vegetation and seems to be the land cover most prone to fires (Ferreira-Leite et al., 2016). Pastoral systems provide an opportunity to manage the fuel load and reduce fire risk in the ecosystem. However, at landscape level, the accumulation of fuel and the continuity of vegetation cover favour the spread of fires, advancing more rapidly in shrub areas than in forests (Torres-Manso et al., 2014). Prescribed fire is a useful management tool, particularly in rangeland areas, improving pasture composition and quality, and can enhance biodiversity (e.g. diversity of habitat types) through patch mosaic burning (Grice et al., 2006).

Stocking density can be affected by the animal requirements, since the genetic structure and potential of the herd evolve, for example for a cattle herd which weight have registered recently a significant increase in their body weight in comparison of their weight 20 years ago, in that case, the stocking density tend to progress assuming the herd's pasture area has not changed during that time (Hersom, 2020). A second element would be the forage species; since differences exist among forage species in terms of growth pattern, forage yield, grazing tolerance, and forage quality (Bransby et al., 1977). Another factor is soil fertility; where deficient soil fertility makes inadequate use of the grazable land area for forage production and grazing (Pringle et al., 2014). The last fact is the environment, represented by seasonal differences which can affect forage growth patterns that will result in stocking density differences (Hersom, 2020).

It is worth mentioning that for small ruminants many factors affect the grazing itineraries, we can notice natural factors like daylight time, maximum and minimum temperatures, stables location and resource availability (Castro et al., 2004),

Comparing itineraries of grazing in a seasonal basis, Torres-Manso et al. (2017) perceive that goats enjoy walking long distances while grazing more than sheep except in summer season where sheep exceed goats in terms of grazing itinerary length since they need more time for resting during the hottest period of the day. The same authors stressed that there is an important correlation between the maximum of daylight duration and the itinerary duration which varies significantly over the year.

It can be quite difficult to define the correct stocking density to avoid invasion of scrub (undergrazing vs overgrazing) (Barcella et al., 2016). For best management, stocking rates should be based on the capacity of the land to carry stock; in this way, the manager must make short-term decisions in response to seasonal conditions (Finch et al., 2014). Stocking rates should be conservative to provide a buffer against declining seasonal conditions and forage availability (O'Reagain et al., 2009). The degree to which animals will penetrate and exploit the more densely wooded vegetation formations depends on animal population density, and a high density may be required to achieve goals such as reduced fire hazard (Schoenbaum et al., 2017).

2.4 Grazing Pressure modelling with GIS

The concept of Grazing Pressure modelling in GIS is built on modelling suitability, movement, and interaction gathers analysis methods have typically been confined to specific disciplines and makes them more widely available (Mitchell, 1999). In the context of geographic information systems (GIS), modelling occurs whenever someone tries to emulate processes in the real world, at a given time or over an extended period of time, having already demonstrated their usefulness in a wide range of applications (Goodchild, 2016). Although, models may be simply formal representations of belief about process or of how various aspects of the real world work, rather than tools for prediction and forecasting (Mitchell, 2012).

Modelling the grazing pressure starts from calculating the stocking density of ruminants and can be used to perceive the distribution of animals in the landscape scale (Barcella et al., 2016).

Allen et al. (2011) highlights that grazing pressure can be evaluated by determining the ratio of animal units or forage intake units per unit forage mass to compare across differences in animal species or stages of production. Over time, a series of instantaneous measures are averaged in order to describe the grazing pressure. Earlier, (Hodgson, 1979) evaluate the grazing pressure by identifying the number of grazing animals of a specified class such us: age, species, physiological status like pregnant, per unit weight of herbage (herbage biomass) and it is well established in general usage.

Another study to consider, is from Bizuwerk & Taddese (2005), who attempt to determine grazing pressure based on the calculation of grazing pressure index. This latter appeals to establish two other measures, the first is the dry matter -that can be produced from each land use and cover type- coupled to the suitability of land use and cover at a defined location, and the second represent the tropical livestock unit.

In order to obtain an evaluation or an estimation of the grazing pressure in a land, we should be mindful that grazing pressure is a notion which is related with spatial distribution of the herds, in order to have an overall view off the effect of ruminants in the study area. In this scope, a recent study made by (Hankerson et al., 2019) lies on modelling the spatial distribution of grazing intensity. The latter authors conceived a spatial model that combines fine-scale livestock numbers with their associated energy requirements to distribute livestock grazing demand into a map of energy supply, with the aim of estimating where and to what degree pasture is being utilized, it will help in evaluating pasture use and available land resources, and can be adapted at any spatial scale (Figure 2).

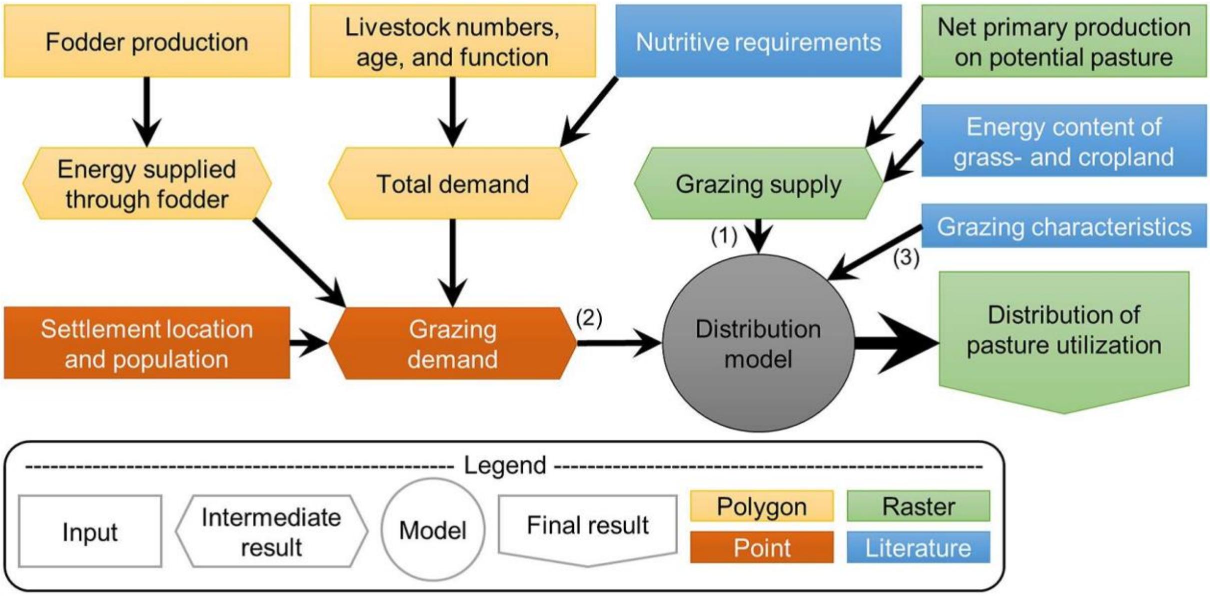

Figure 2: Flow chart for the distribution of utilized pasture in modelling the spatial distribution of grazing intensity in a study made by Hankerson et al. (2019).

Schoenbaum et al. (2017) made spatial distribution analyses based on animal locations at which activity was classified as grazing, where locations were linked to the various GIS layers (vegetation, topography, and management data), and the distance of each location from management factors (water, feed, fences) was calculated.

Barcella et al. (2016) tunes that grazing pressure was estimated using the spatial data from field observation. It was calculated as the product of the number of animals present in a polygon and the duration of stay according to Ausden (2007). Besides, he considered the total number of animals present in a polygon for a given time interval, not taking into account the recorded animal behaviour. Then, the number of animals was converted into number of livestock units (LSU) using standard coefficients, established on the basis of the nutritional or food requirement of each animal type. In addition to that, the grazing pressure for each sampling date was then calculated on this previous study on a grid of 5 m*5 m square cells (livestock units*h/25m^2). The grazing pressure for the whole sampling period was obtained by summing the daily grazing pressure for each grid cell. Daily stocking rate (livestock units*day/m^2), was calculated as the sum of all single grazing pressure values (livestock units*h/m^2) recorded for each mapping date. Besides, the daily stocking period was calculated as the observed daily time spent by the cattle herd in the pasture (excluding time spent by animals in the resting areas) weighted by the daily grazed area for each mapping date.

Kussul et al. (2017) interpreted that determining the land-use pattern of livestock is difficult; so far, his primary focus has been on land used for crops, due partially to the fact that it is easier to detect accurately with remote sensing. Unlike cropland, pasture often consists of natural grassland, and differentiating grassland and pasture using remote detection is an arduous task that as of yet has no universal solution (Kuemmerle et al., 2013).

Several products attempt to map land use and cover on a global scale, Erb et al. (2007) utilized a subtractive approach with differing classifications and definitions, while Goldewijk et al. (2007) used different allocation rules that combine remote sensing-derived land cover with national statistics. Likewise, global remote sensing products often have lower classification accuracies for grassland ecosystems, particularly in areas where transition classes and ecotones are common (Gong et al., 2013).

Regarding modelling of grazing pressure, Coppolillo (2001) come out with 4 types of conceptual models of grazing pressure demonstrated in the Figure 3 below, each model depends on the time of year ;

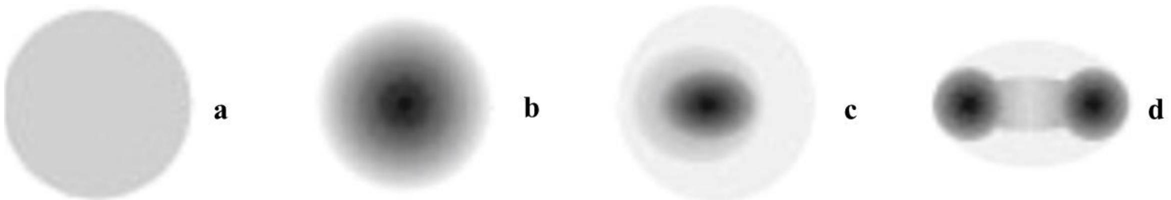

Figure 3: Conceptual models of grazing pressure developed by Coppolillo (2001)

Looking at Figure 3, we can cite Model a, which assumes that the intensity of grazing is evenly distributed over a radius of eight kilometres around the pastoral settlements (Rodgers, 1991). This means that animals spend more time grazing farther away from the camp and that grazing intensity is uniform with regard to direction. Model b assumes that grazing intensity decreases with distance away from pastoral settlements and that grazing intensity is uniform with regard to direction (Spencer, 1973). Model c assumes that grazing intensity decreases with distance away from the pastoral settlements but that is skewed towards the direction of water (Spencer, 1973). And the last one is Model d that assumes that grazing intensity decreases with distance away from the pastoral settlements but that animals move between a pastoral settlement and a water source as they are watered every other day (rather than everyday) (Western, 1975).

In this study, we are in an unconstrained model, in which animals range freely and are not tied to a specific place, which have been used to describe grazing systems in North America, Australia, and Europe, including systems in which animals are enclosed in fenced pastures. More accurately, we will adopt the Model b (Moritz et al., 2010), assuming that each model can be used depending on the period of the year, and that the discovery of the water points is much more important in summer.

3 Materials and methods

3.1 Study area

The area under study is the district of Bragança, covering 7.4% of the Portuguese national territory. It is administratively divided into twelve municipalities and 299 parishes located in the northeast part of the "Trás-os-Montes e Alto Douro" region. It is bordered by Spain in the north and northeast, Vila Real District in the west, Viseu District in the southwest and Guarda District in the south. It encompasses a total area of 6598,55 km², with population density of 22 hab./km², below the Figure 4 presenting the district of Bragança, with mentioning in it the location and headcounts of herds existing there.

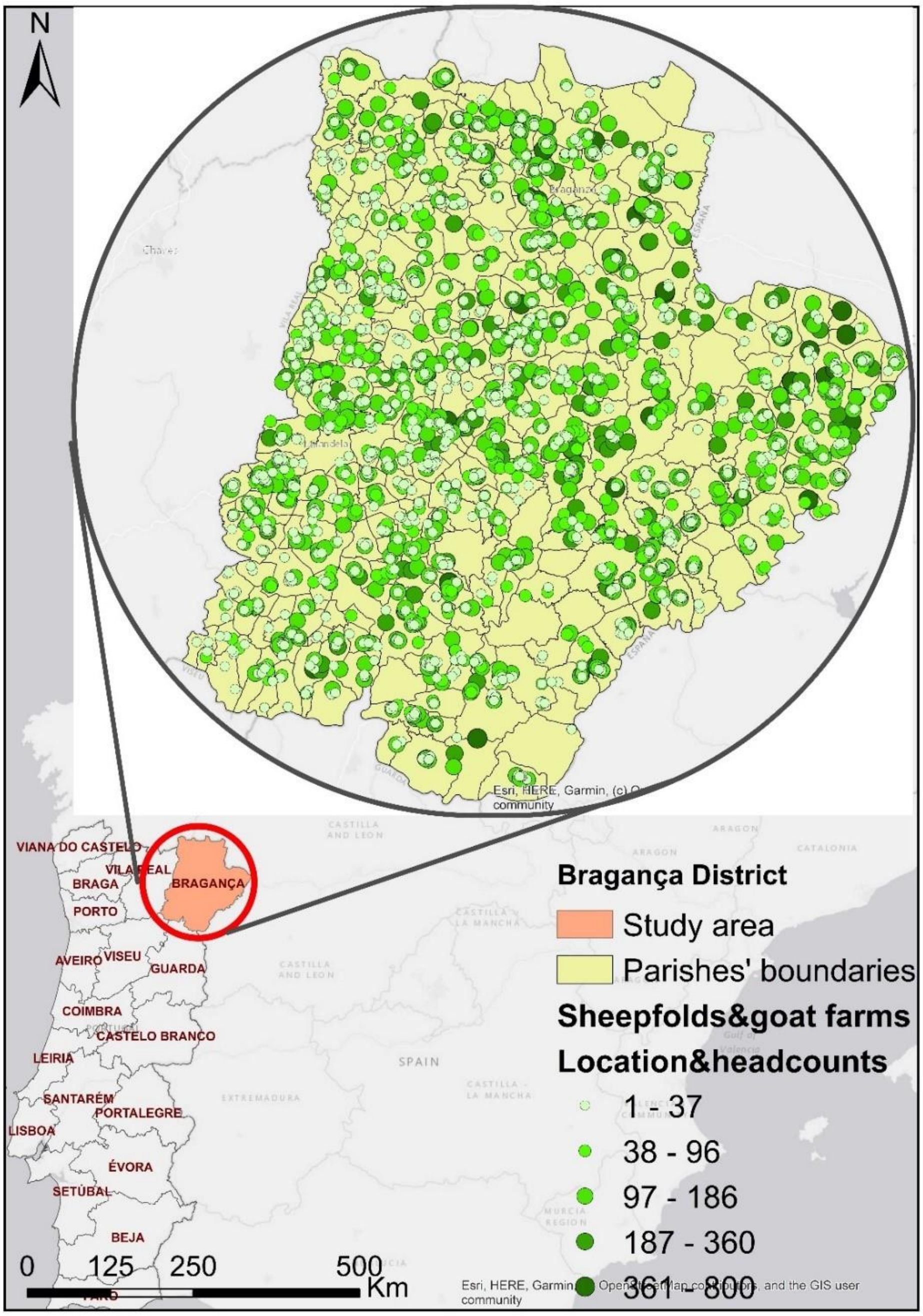

Figure 4: Map representing the location and headcounts of herds in the district of Bragança

3.1.1 Geography

The district is composed of two distinct regions described in terms of its geographic differences: the northern areas, with the higher altitudes constitute the "Terra Fria Transmontana" (Cold lands), and the "Alto Trás-os-Montes", where the landscape is dominated gentler slopes of the plateau; and the southern areas, the "Terra Quente Transmontana" (Hot Lands), where the climate is milder, marked by the valleys of the Douro River and its tributaries. Its area allows a wide diversity of landscapes, and the district is known for its rugged geomorphology, and an aging population and urban to rural migration of its residents over time.

It is the Douro River that characterizes the geography, dividing the borders within the district, its southern frontier and extreme northeast borders with Spain. In addition to that, Bragança includes several natural sanctuaries, such as the Montesinho Natural Park, the Douro International Natural Park, and the Protected Landscape of Albufeira do Azibo.

Furthermore, we can classify the land-use covering our study area into 8 classes which are; annual crops, permanent crops, grasslands, shrublands, grazed forest which are all grazed areas, the ungrazed ones are eventually ungrazed forest, water sources and urban areas.

In Figure 5 we present a mosaic of landscapes of the region (photos of the author or under license). The sequence from above illustrates the 4 main types of permanent agriculture, from left to right, vineyard, chestnut orchard, olive grove and almond trees. In the centre a flock of sheep that moves through the road network, on the left a permanent landscape with a fence dedicated to cow herding. On the right, a permanent pasture grazed by sheep. Below, on the right, a rough landscape of a valley excavated by a stream over time and with cliffs that are grazed mainly by goats, and also by sheep in less steep situations. It has a type of endemic shrubby and low arboreal vegetation. The 3 remaining low images are two types of association of pasture and native forest, the one on the left with holm oak, and the others with cork oaks and other deciduous trees, in this case ashes. In the second photo on the left below we can see an artificial lake and its dam (Parish of Penas Roias, municipality of Mogadouro, District of Bragança).

Figure 5: Mosaic of landscapes of the Bragança region representing different grazing areas (permanent crops at the top, pastures in the middle, grazing forest and shrubs at the bottom)

3.1.2 Climate

District of Bragança is typical of having a dry Meso-Mediterranean climate with temperate summer.

It has a harsh climate where the winter is very cold and the summer is very hot because of its location in a mountainous area, the district is known for its climatic differences ("nove meses de Inverno e três de inferno" which means "nine months of winter and three of hell"). Moreover, the average altitude is estimated at 585 m. The minimum elevation is 458m, near the Douro River, to the south, and the maximum reaches 1095m at the northern top, in Serra do Montesinho. The temperature decreases with altitude and this explains why in the region of "Terra Quente Transmontana", with lower average altitude, it is warmer than in "Terra Fria Transmontana", whose average altitude is higher.

3.2 Databases

In order to achieve the objective of this work, we use four main supplies as presented in subsequent;

COS2018 (Carta de Uso e Ocupação do Solo de Portugal Continental – 2018) (DGT, 2019) is the latest thematic cartography that aims to characterize in great detail the land use and cover in the territory of Mainland Portugal. COS is a cartography which had been produced since 1990; in our study we use that of 2018 and overlay it with the study area. COS2018 is a mapping of polygons, which represent homogeneous land use and cover units with a minimum cartographic unit of 1 hectare and a minimum distance between lines of 20 meters. This cartography was produced based on the visual interpretation of high spatial resolution orthorectified aerial images, according to the officially adopted nomenclature.

The nomenclature of land use and cover map of mainland Portugal (DGT, 2019), which is the second tool, is made up of classification of the land use and cover into 4 levels; the first level has 9 main classes of land use and cover which are: artificialized territories, agriculture, grasslands, agroforestry surfaces, forests, shrublands, open spaces or little vegetation, wetlands, and surface of water bodies (Annex I). Each class section is divided into several sub-sections, and so forth till the fourth level. The Figure 6 highlights the main classes from the first level and some of the other levels to have an overall idea of the type of vegetation covering the mainland of Portugal and similarly we applied this classification to Bragança region.

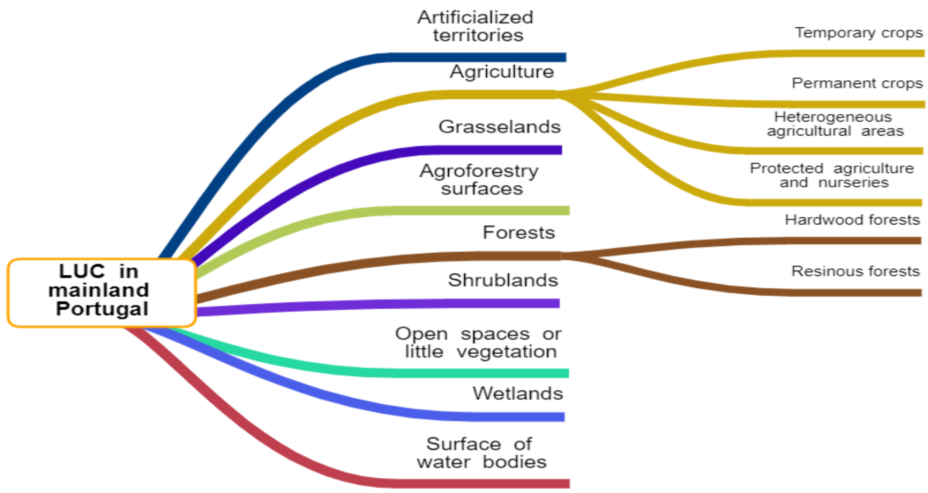

Figure 6: Schema of the main classes of land use and cover in the mainland of Portugal

We proceed to an aggregation of the areas in 8 land use and cover classes (Table 1).

CAOP 2012 (Carta Administrativa Oficial de Portugal – 2012.1) (DGT, 2012) is the Official Administrative map of Portugal. CAOP records the state of the delimitation and demarcation of the country's administrative districts. It displays several polygons existing in each parish, with the area that occupies. It is fundamental to define the animal grazing area, because the grazing area of small ruminants is fenced by the parish surrounding the sheepfolds and goat farms. The parishes' boundaries of the study area are displayed in the Figure 4. The last information used is the livestock locations defining the distribution of sheepfolds and goat farms all over Bragança, with the number of headcounts being there (Figure 4). It is afforded by "Observatório Transfronteiriço de Sanidade Animal (OTSA, 2010) of IPB. It has been recorded in an inventory period from the beginning March 2009 to the end December 2010, reflecting the geographical location of each stable and its livestock. This tool would be useful to carry out a prediction map showing the grazing pressure.

In the same context, we have been interested in sheep and goat herds for itinerant grazing. Herds are diluted by daily journeys of varying distance. The stocking densities derived from herds can be spatially interpolated. Cattle, on the other hand, are mostly confined to fenced areas and have not been included in this study.

3.3 Geoprocessing

Geoprocessing is a framework and set of tools for processing geographic and related data. The comprehensive suite of geoprocessing tools can be used to perform spatial analysis or manage GIS data in an automated way. A typical geoprocessing tool performs an operation on a dataset such as a feature class, raster, or table, and creates a resulting output dataset. For example, the Buffer tool (which we will employ in our work) takes features as input, creates buffer areas around the features to a specified distance, and writes those buffer areas to a new output dataset, more details will be presented further. In addition to the suite of tools, geoprocessing is also a powerful framework that supports control of the processing environment and allows to build custom tools that can further automate the work.

3.3.1 Geographical information compilation

We clip COS2018 by the boundaries of the study area (Bragança district, according to CAOP2O12) and, in order to recognise the land use and cover of our interest, in particular the type of vegetation being grazed by small ruminants, we proceed to a rational aggregation of the areas into 8 land use and cover classes described in Table 1. We have overlaid the points corresponding to the stables (OTSA ShapeFile), with the information of the livestock in each of them.

3.3.2 Land use and cover mapping

First of all, in order to identify the grazing pressure all over an area, it is of paramount importance to inquire about the land use and cover of the area under study; Bragança region; so as to know the type of vegetation and the preferences of ruminants, by identifying the classes which are under high or lower pressure. For that purpose, we use the nomenclature of the Land Use and cover map of mainland of Portugal (DGT, 2019), with its different levels of classification showing detailed information, and we made a new classification. We define each class in the Table 1 presented below:

Table 1: Land use and cover classes for Bragança region

Class name	Descriptions
Annual crops	Arable land, worked regularly, usually on a crop rotation system. Land cover with bare ground in July after crop harvest (brown and white soils in true colour composite images).
Permanent crops	Permanent crops Consist mainly of vineyards, olive groves, chestnut and almond orchards. Land cover with a rough texture and with a repetitive pattern.
Grasslands	Grasslands 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	Shrublands 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 and Ungrazed Forests	Forests are 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	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	Rivers, reservoirs and lakes. Dark tone due to reduced overall reflectance.

The second approach tends to apprehend the itineraries of the small ruminants including sheep and goats. The concept consists in assuming that the herds roam a distance of more or less 5 km (of round trip) conditioned by respecting the parish boundaries, since it’s the area allowed for grazing.

Besides that, the input data was the number of headcounts existing on each sheepfold and goat farms, we set up by using GIS to generate a prediction map as output, holding the grazing pressures all over the study area; it’s a geoprocessing step.

Geoprocessing distributes grazing pressure evenly across all land use and cover classes. The next step will be to transfer the grazing pressure allocated to the ungrazed classes to the classes that are of interest for grazing analysis. It obviously makes no sense to have grazing pressure in lakes, for example.

3.3.3 Stocking density assessment

To have an overall view about the headcounts existing in sheepfolds and goat farms, we made a histogram displaying the number of animals in function with the number of sheepfolds and goat farms, and it shows a lot of ruminants are concentrated in a few number of herds locations

(Figure 7). For this reason, we've choose to take into account only the herd farms comprising 20 heads and more, to have a representative and significant results.

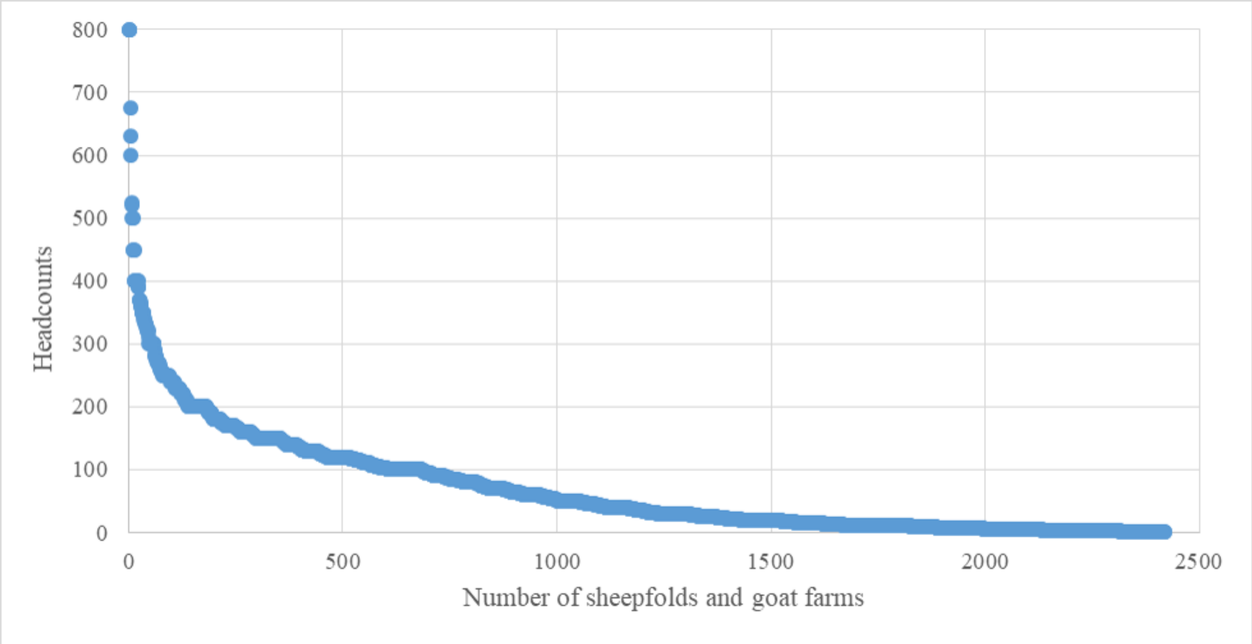

Figure 7: Histogram presenting the shape of headcounts in function with the number of livestock

The flocks of Bragança region vary between 20 and 800 sheep and goats, with a totality of 157,858 headcounts, and a mean of 104 small ruminants per holding.

The target is to know the spatial distribution of the livestock. For that purpose, we use a multiple ring buffer tool which creates multiple buffers at specified distances around the input features which is the livestock locations. The distances pursuing a geometric progression that we choose are successively: 100, 200, 400, 800, 1600, 3200, 6400m as radius around the livestock locations; considering that the latter is the maximum distance that can be crossed by the flocks on a daily itinerary (Castro et al., 2016). By moving around their sheepfolds and goat farms through these radius, we assume that the headcounts of herds have a downward trend in a gradual way. In this perspective, we calculated the stocking density (number of animals/ha) for each ring apart, to avoid the reiteration of headcounts from the previous ring, thus the stocking density is decreasing from a ring to the subsequent one.

Thereby, the stocking density is defined as the headcounts of small ruminants per area (in hectares). Assuming that each buffer zone can be grazed by different animals from different locations from the same parish, we maintained all buffer areas regardless of these overlaps so that each buffer will cover its input feature plus the area of any smaller buffers. Besides that, as there are several herds in each parish, the number of livestock per hectare is accumulated where multiple polygons overlap (Figure 8). To issue the overlapping task, we create a fishnet of rectangular cells with an edge valued of 1000m. This network allows a systematic distribution of points covering Bragança district as the extent.

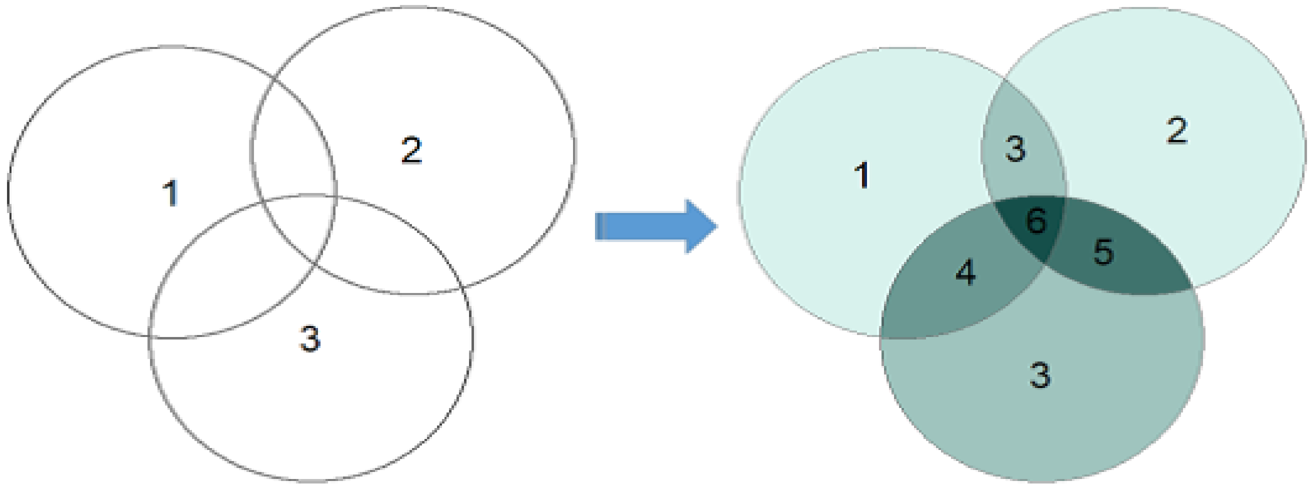

Figure 8: Sum of values for areas where multiple polygons overlap

3.3.4 Spatial join and spatial interpolation

Having in our disposal the stocking density (number of animals/ha) for the area surrounding the livestock locations and the spatial network of the study area, we carry on a spatial join matching attributes of the two features based on their relative spatial relationship, in addition to that, the rule of aggregation is based on summing the value of stocking densities.

The result is displayed as the intersection of each point from the spatial network with the buffer area to generate stocking density existing in the cells covering the entire area. From this spatial join containing the stocking density information, we performed a spatial interpolation. We assume that the locations are a continuous surface, the interpolation consist in estimating the attribute values of locations that are within the range of available data using known data values. Thus we use two methods; inverse distance weighted (IDW) and kriging method to perform a prediction map of grazing pressure.

Spatial interpolation with inverse distance weighted

The first method of interpolation (IDW) determines cell values using a linearly weighted combination of a set of sample points; which is the livestock locations, it is a local method which is exact and that can be linear or non-linear. The weight (influence) of a sampled data value is inversely proportional to its distance from the estimated value. The variable interpolated should be dependent on the spatial distribution (Shen et al., 2012), and in our case the stocking densities depend on the distance of grazing. This method assumes that the variable being mapped decreases in influence with distance from its sampled location (Philip et al. 1982). As far as we concerned, when interpolating the surface generated from spatial join of buffers and the network, the stocking density of a more distant location will have less influence because small ruminants are more likely to graze closer to their sheepfolds and goat farms. Moreover, we investigate an optimal value of the power which is 1, it’s where the minimum mean absolute error is at its lowest in this study, for example, Ping et al. (2004) used inverse-distance weights of powers 1 through 5 to determine the spatial weights matrix for modelling autocorrelation functions

The IDW is defined by the equation **(**1**)** below where Z_P is the value of the unknown point and Z_i is the value of known points and di is the distance between the known point and unknown point.

$$Z_p = \frac{\sum_{i=1}^{n}\left(\frac{Z_i}{d_i^p}\right)}{\sum_{i=1}^{n}\left(\frac{1}{d_i^p}\right)} \qquad \textbf{(1)}$$

Interpolation in GIS works with the same principle as in math; it takes known points and create a surface by estimating unknown ones (Watson et al. 1985). In other words, it works as following:

- Find the neighbouring sample points of the target location (i.e. through *n* nearest neighbours or a search radius);
- Find the distance from each sample point to the target location;
- Weight each sample point according to the inverse of its distance from the target location taken to the *r* exponent;
- Average the weighted attribute values of the sample points and assign the resulting value to the target location.

The IDW (inverse distance weighted) is a deterministic interpolation method because it is directly based on the surrounding measured values or on specified mathematical formulas that determine the smoothness of the resulting surface (ESRI, 2016a).

Even if the Inverse Distance Weighting interpolation method is as flexible as they come, it’s often the case that other interpolation techniques like kriging can help obtain a more robust model (Rahman et al. 2010).

Spatial interpolation with kriging

The second method adopted are the one that generate a prediction map. Kriging is defined as an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with z-values. Unlike other interpolation methods in the Interpolation toolset, to use the Kriging tool effectively involves an interactive investigation of the spatial behaviour of the phenomenon represented by the z-values before selecting the best estimation method for generating the output surface (Burrough et al., 1986).

Kriging is based on statistical models that include autocorrelation—that is, the statistical relationships among the measured points. Because of this, geostatistical techniques not only have the capability of producing a prediction surface but also provide some measure of the certainty or accuracy of the predictions (Press et al. 1988).

Namely, kriging assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. This tool fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. It is a multistep process (Olivier et al. 1990); including exploratory statistical analysis of the data, variogram modelling, creating the surface, and (optionally) exploring a variance surface. Thus Kriging is most appropriate for this work since there is a spatially correlated distance in the data. To sum up, Kriging assumes using the data twice, the first time to estimate the spatial autocorrelation of the data to uncover the dependency rules and the second to make the predictions (Heine, 1986). It is appended to the concept of variography; Fitting a model, or spatial modelling, is also known as structural analysis, or variography. In spatial modelling of the structure of the measured points, we proceed with the empirical semivariogram, computed by the difference squared between the values of the paired locations. The Figure 9 below shows the pairing of one point (the red point) with all other measured locations. This process continues for each measured point.

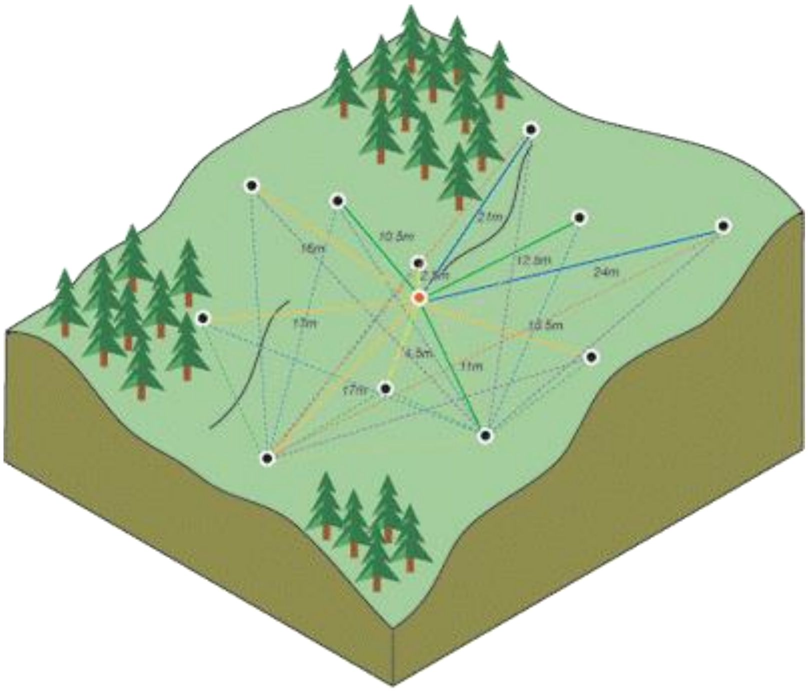

Figure 9: Illustration of variography by pairing one point with all other measured locations (ESRI, 2016b).

Semivariogram model is represented as below (Figure 7), it has different adjustable parameters on which we can act. Besides, the use of the semi-variogram displaying such a curve assumes that the items being nearby tend to be more similar than those being more distant from the unknown point. Also, the interpolation is made based on the known sample points, by plotting the semi-variogram, we can have all the points covering the area.

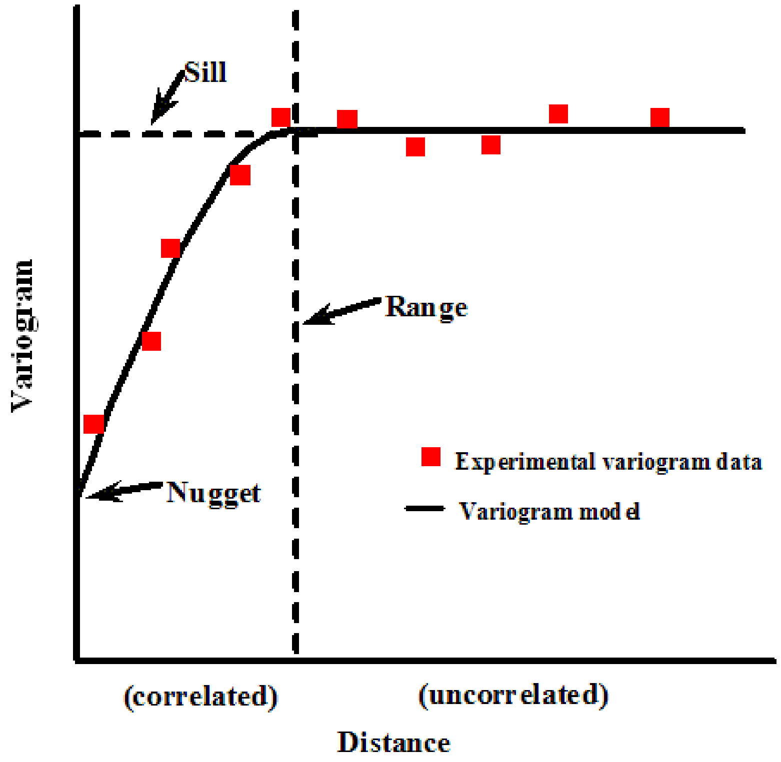

Figure 10: Illustration of variogram and its components (VPS, 2020)

After all, in the experimental variogram (Figure 10), the distances between pairs at which the variogram is calculated are called lags. The number of lags specifies how many lags of the variogram to calculate. This, together with the distance between lags, determines the maximum distance between pairs of points at which the variogram is calculated. This maximum distance is called the variogram coverage (number of lags times the distance between lags), and is displayed on the dialog. The variogram coverage should be less than the site size, and a good guideline is for the variogram coverage to be closer to ½ - ¾ of the site size (McBratney, 1986).

In practice on GIS, we carried out different simulations to have more reliable and exact results presenting the lowest value of mean error. The use of ordinary kriging rather than simple kriging is explained by the fact that ordinary kriging is more accurate and more reliable (Daya & Bejari, 2015).

In fact, the selection of a lag size has important effects on the empirical semivariogram (Gribov et al., 2006). For example, if the lag size is too large, short-range autocorrelation may be masked. If the lag size is too small, there may be many empty bins, and sample sizes within bins will be too small to get representative averages for bins. When samples are located on a sampling grid, the grid spacing is usually a good indicator for lag size, which is the case in this work, we’ve proceeded previously to create a fishnet of rectangular cells with an edge valued of 1000m, thus a simulation will be based on choosing the grid spacing as a lag size (*ESRI, 2016c*).

A simple rule is to multiply the lag size by the number of lags, which should be about half the largest distance among all points. The Figure 11 shows that the largest distance among all livestock locations is valued of 106.7 Km. Also, another parameter is the major range that represents a distance beyond which there is little or no autocorrelation among variables. In this context, if the range of the fitted semivariogram model is very small relative to the extent of the empirical semivariogram, we decrease the lag size. Conversely, if the range of the fitted semivariogram model is large relative to the extent of the empirical semivariogram, we increase the lag size.

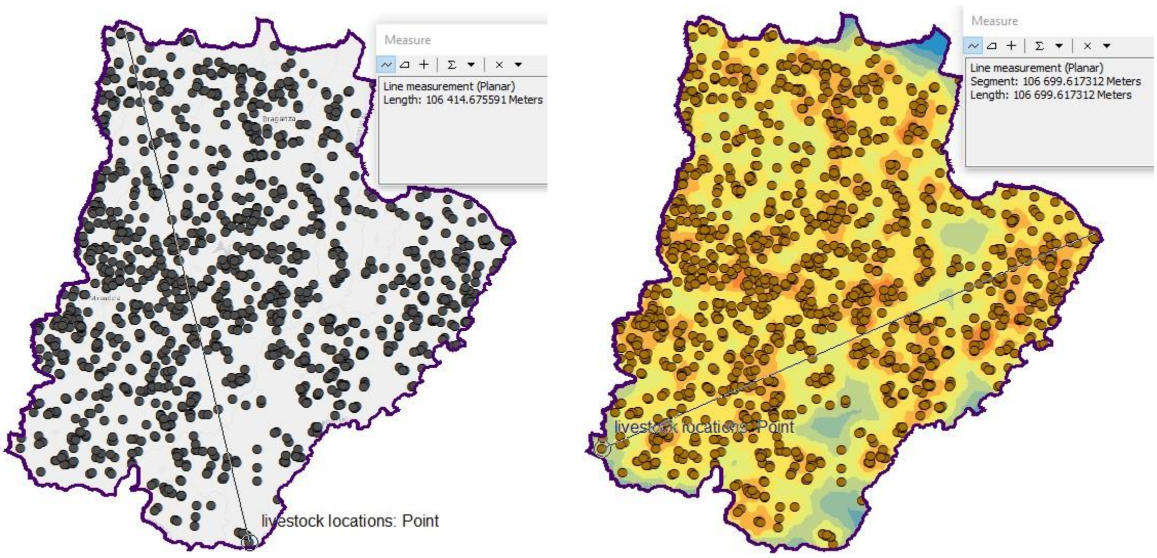

Figure 11: Definition of the largest distance between livestock building among the study area using GIS

Another thumb rule is based on using the average nearest neighbour tool as a lag size (Seidl et al., 2015). It determines the average distance between points and their nearest neighbours. This provides a reasonably good lag size, as every lag will have at least a few pairs of points in it. The distance method is automatically set to Euclidean distance. Thus we use NNO (nearest neighbour observed) and make assumptions for the semivariogram modelling (Figure 12).

Figure 12 : Extraction of data of the nearest neighbour using GIS

Based on that, we can determine the number of lags with a simple calculation (applied in the third simulation):

- lag size x number of lags = half the largest distance among all points
- number of lags = half the largest distance among all points / lag size

The best simulation is the one showing the lowest value of mean error; generally, the best model is the one that has the standardized mean nearest to zero, the smallest root-mean-squared prediction error, the average standard error nearest the root-mean-squared prediction error, and the standardized root-mean-squared prediction error nearest to 1 (Zheng et al., 2009).

The kriging tool generate a prediction map, showing different levels from stocking density, beginning with 0 and finishing with 204 ruminant (sheep or goat) per hectare (Figure 17). The next step consist in transformation of the prediction map generated by kriging into a raster using GA layer to grid tool with a resolution of 25m (Figure 20). The stocking densities data afforded by this raster need one more step to be qualified as grazing pressures. In fact, the grazing itineraries follows-up by livestock doesn't include some areas for instance water, urban areas and ungrazed forests. It represents 13% from all classes of land use and cover. For that reason, we will take into account only the grazed area that represent 87%; so we will proceed to a sort of allocation of the 13% on all the grazed classes. In practice in GIS, the raster obtained from the predication map will be divided into 0.87.

After that we will work on COS2018 map by splitting it into two categories apart, we affect a Boolean function with 1 for grazed areas, and 0 for ungrazed ones. This function will be helpful to affect the grazing pressure information only in the grazed areas. Then we proceed to convert the map to a raster file displaying only the two classes.

3.3.5 Generating of the grazing pressure model

This step consists in multiplying the values obtained from the two raster files (raster from the Land use and cover map and the grazing pressure raster) using times tool.

Subsequently, we will proceed to reclassify the values of grazing pressure obtained into 10 classes, so as to have the values of grazing pressure all over Bragança district. And finally we perform an assimilation based on LUC classes, when we will compare between the grazing pressure and LUC availability to come out with conclusions regarding the intensity of grazing pressure affecting each LUC class.

4 Results and discussion

To validate the adopted methodology, results of the geoprocessing with geographic information system must be identified.

4.1 LUC Classification applied to the study area

Firstly we start with the classification of the land use and cover of Bragança region Table 1, obtained from grouping land use and cover information from the nomenclature of the land use and cover Map of mainland Portugal (Annex I) and therefore displaying the eight classes in LUC map, showed below (Figure 13):

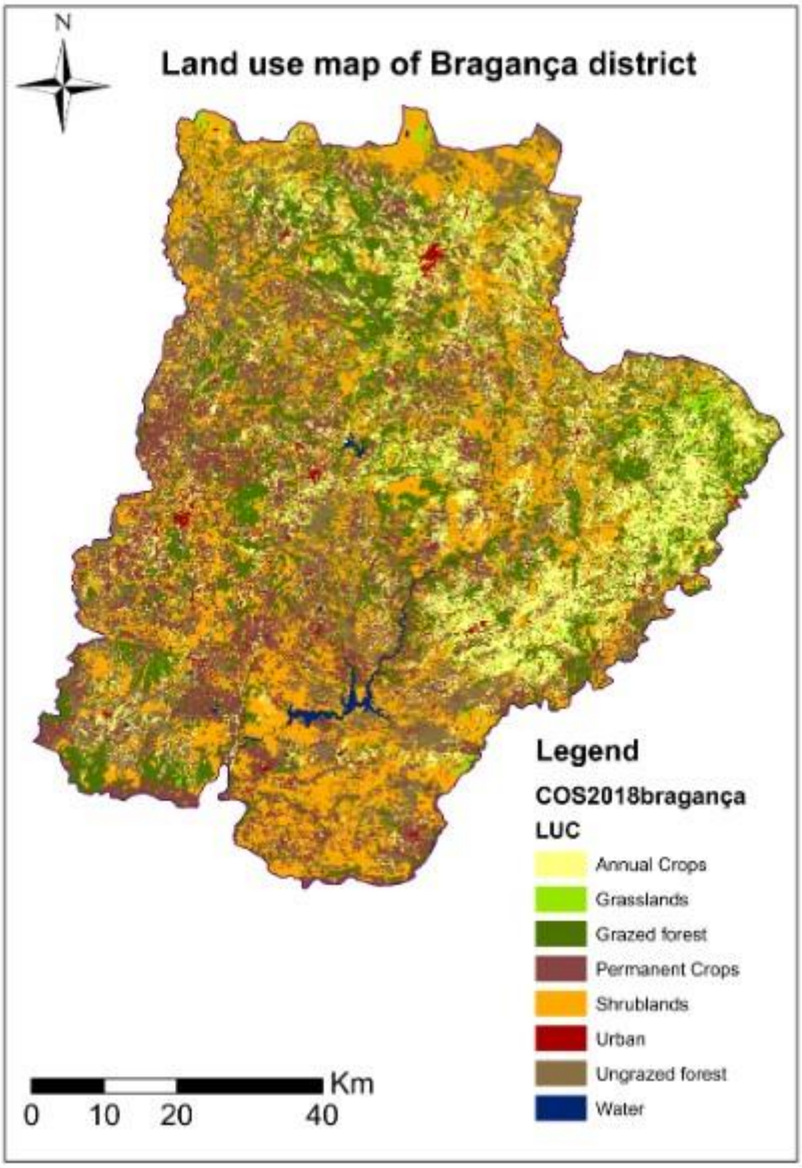

Figure 13: Land use and cover map in Bragança region

4.2 Identification of stocking densities of the herds

The second step of the work consist in exploiting the locations of sheepfolds and goat farms which informs about the headcount, which is considered as defined samples with known values that has a major role to evaluate the distribution of grazing pressure all over Bragança region through variography. The Figure 14 below shows different sizes of ruminant extending almost over all the study area. The number of sheep and goat vary from 20 to 800 with an average of 104 ruminants per holding.

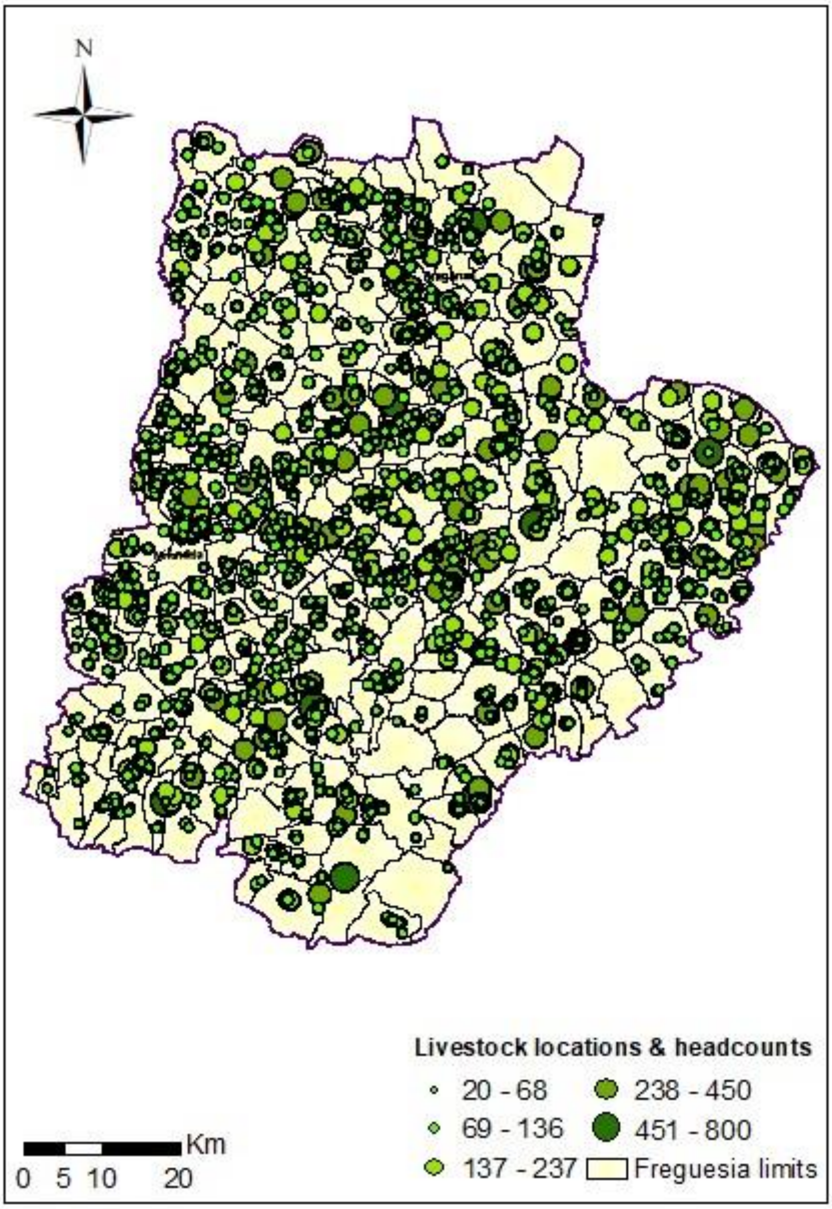

Figure 14: Map of distribution of the livestock (sheep and goats) in Bragança region

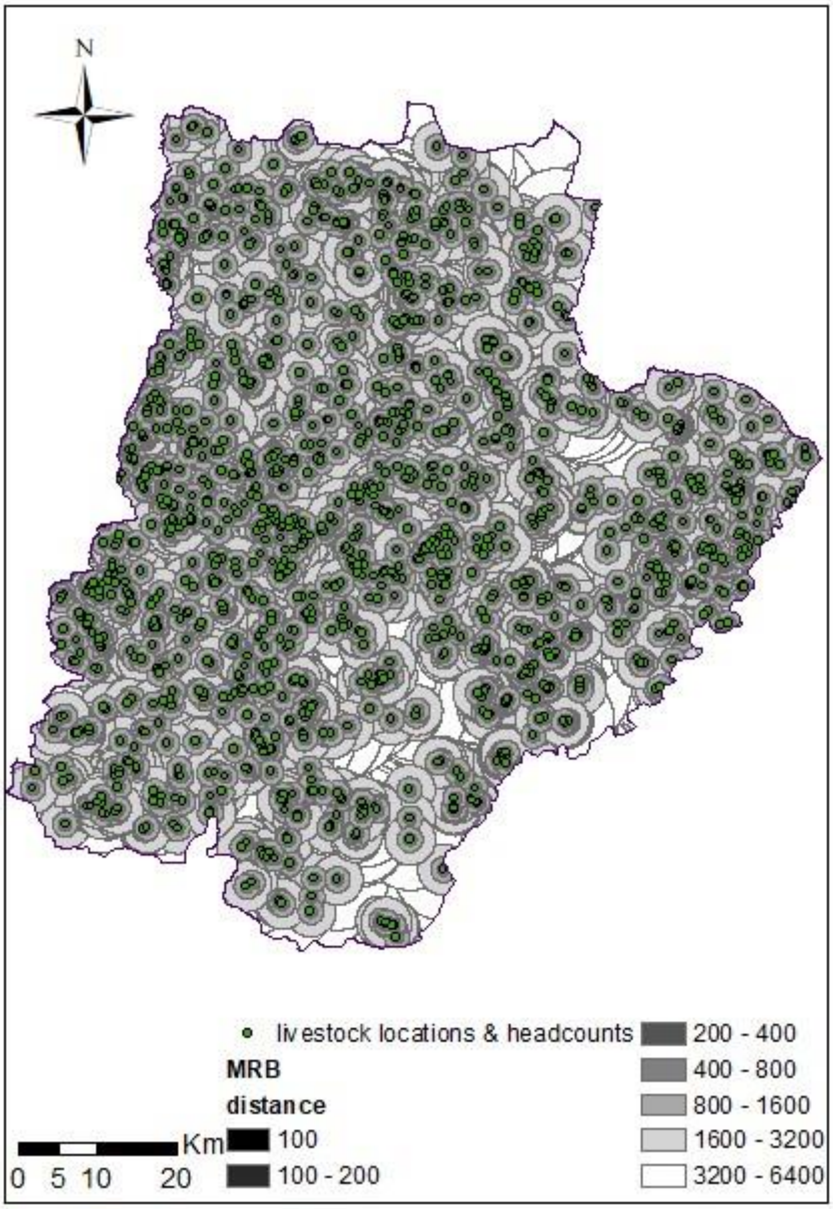

Figure 15: Map of multiple ring buffer

As the animals move away from their buildings, subsequently the herd is gradually diluted by the larger area (Table 2), the effect of which was estimated by using the Multiple Ring Buffer tool with 100, 200, 400, 800, 1600, 3200, 6400m of radius (Figure 15). The farthest distance comes out with the lowest stocking density (Moritz et al., 2010) as shown in the Table 2 below. The buffers surrounding the herds locations has different stocking densities.

Table 2 : Stocking densities of small ruminants in buffer zones

	SD (sheep or goat/ ha)		
Radius of Buffer Zone	Mean	Min	Max
100	33.12	6.33	254.64
200	11.04	2.12	84.88
400	2.76	0.53	21.22
800	0.69	0.13	5.3
1600	0.17	0.03	1.32
3200	0.04	0.01	0.33
6400	0.01	0	0.08

4.3 Results of spatial interpolation

4.3.1 Method of IDW

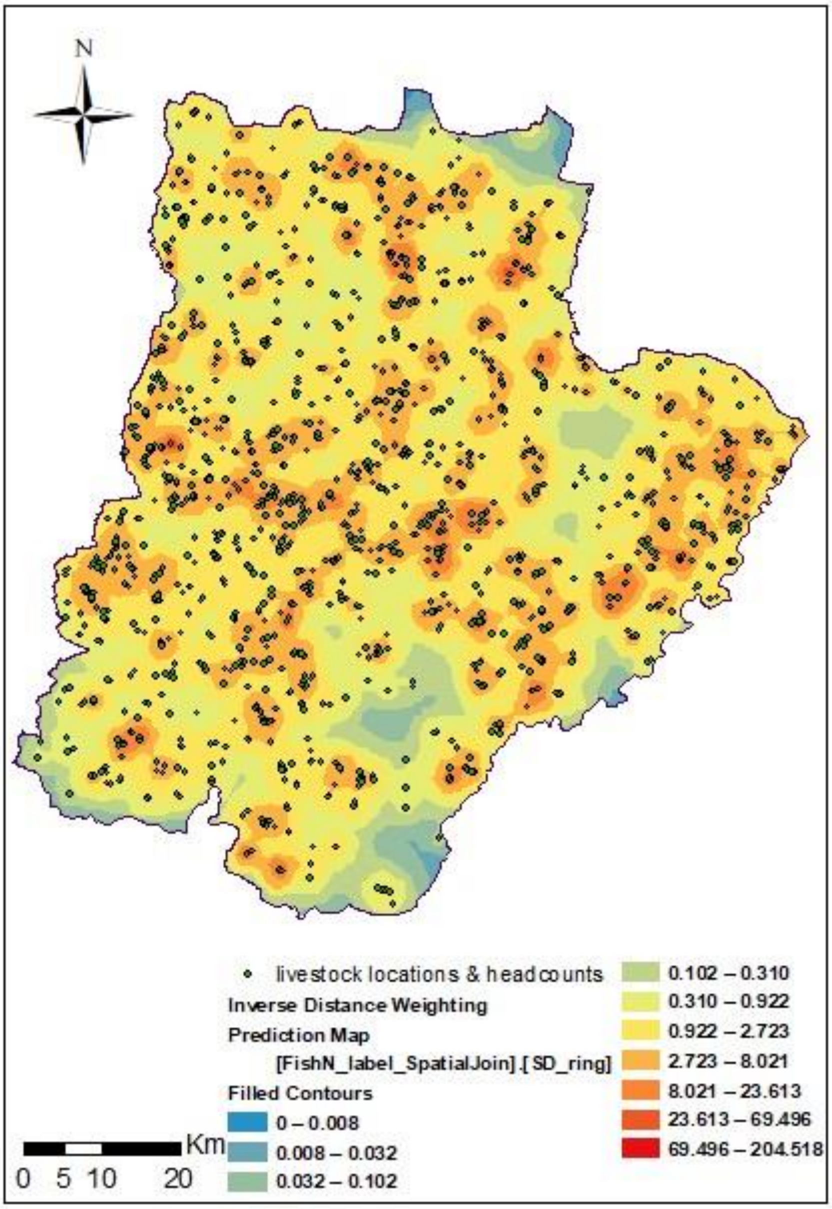

Figure 16: Prediction map generated with Inverse distance weighted

Using IDW tool has generated a prediction map (Figure 16) representing stocking densities in a raster file in the study area. It shows that the herds are concentrated in the east, the middle and some areas above and below.

We caution that it is an evidence that the areas representing low level of predicted stocking densities are the ungrazed ones (water, ungrazed forest and urban) which we have defined previously. Nevertheless, another explanation can be that low stocking densities are the ones which are not grazed by ruminants, and that can be any class of LUC since it has low plant species diversities (Kikoti & Mligo, 2015). We append that ruminants have some preferences toward specific type of vegetation (Wyffels et al., 2009). Consequently, the grazing pressure will vary in each class of land use and cover.

We've choose to execute IDW with a power of one. According to Weber and Englund (1994), IDW with a power of one resulted in a better estimation for data. The cross validation shows a mean error of 0.0012, and a root mean square valued 6.30. In an attempt to improve accuracy, kriging was performed.

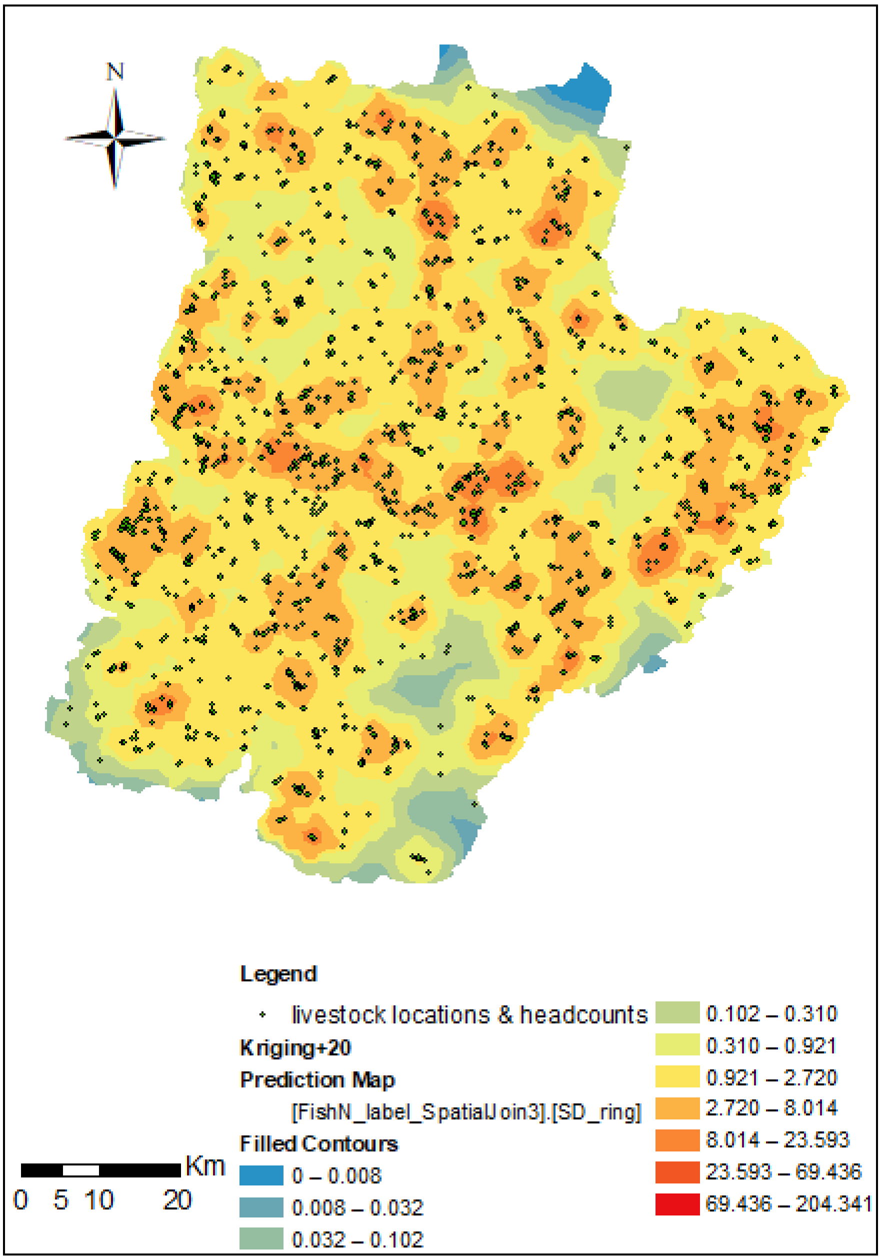

Figure 17: Prediction map generated by kriging

The kriging simulation was done by changing one or more parameters of the semivariogram model each time, trying to improve the interpolation, whose results are presented below (Table 3):

Table 3: Simulations made in variography modelling

Nb of simul	**type or level of change**	**lag size**	**Nb of lags**	**range**	**ME**	**RMS**	**MSE**	**RMSS**	**ASE**
1	no change	508	12	3352	0.0008	6.18	0.00014	1.107	5.588
2	Optimization	12377	12	99013	0.0008	6.18	0.00014	1.105	5.602
3	lag size = NNO	594	90	1822	0.0003	6.223	0.00005	1.088	5.719
4	range	594	90	50000	0.0004	6.1	0.00009	1.210	5.100
5	range and nb of lags	594	90	3000	0.0006	6.183	0.00010	1.103	5.608
6	Nb of lags	594	70	1911	0.0003	6.22	0.00005	1.089	5.714
7	Nb of lags	594	30	1911	0.0003	6.22	0.00005	1.090	5.710
8	lag size= NNE	1187	45	1822	0.0003	6.223	0.00005	1.088	5.719
9	Nb of lags	1187	30	1822	0.0003	6.223	0.00005	1.088	5.719
10	Lag size = grid spac.	1000	25	1822	0.0003	6.22	0.00005	1.088	5.719

Mean error (ME); Root Mean Square (RMS); Mean Standardized (MS); Root Mean Square Standardized (RMSS); Average Standard Error (ASE)

As we can see in the Table 3 , the mean error and the other prediction errors (RMS, MS, RMSS, ASE) are very close in almost all simulations.

After the two first simulations, the results show a better mean error (mean error= 0.0003). The 4 simulation is based on increasing the major range, which doesn't been successful, since it shows a big difference between the semivariogram model and the extent of the empirical one. After that we tried in the 5th simulation to decrease the range which also hasn't been successful (the mean error has increased). In the next simulation (S6) we acted on the number of lags which shows a better result of mean error (0.00029), even though the shape of the semivariogram showed an excessive binned points which will not let show a representative average for bins. Therefore, we attempt to reduce the number of lags to 30 in the simulation 7, and it shows the lowest value of mean error, and a better shape of the semivariogram as the Figure 18 exhibit. At the level of the simulations (S8 and S9) we have proceeded to increasing the lag size to the value of nearest neighbour expected (NNE), and also we changed the number of lags, however it doesn't show up any significant difference with the other simulation, because the mean error didn't change (0.0003). The last simulation is built on the rule that the grid spacing is a good indicator for lag size, the result is also the same (mean error = 0.0003).

The predictions are unbiased, the ME (mean error) should be almost nil, but because of its weaknesses due to its dependence upon the scale of the data and to its indifference to the wrongness of semivariogram, ME is generally standardized by the MSE (mean standardized error), being ideally near zero (Arétouyap et al., 2016). From all the simulations we judge that the best one is the 7th because it shows the lowest mean error (0.00029) near 0 which reflects a good representation of spatial variability, the mean standardised error with a low value near zero increase the quality of predicting.

The shape is representative and significant since the range of the semivariogram model fits the extent of the empirical semivariogram (Figure 18).

As presented in Table 4, we obtain an ASE(Average Standard Error)= 5.71 < RMS(Root Mean Square) = 6.22, so we are in an under-estimation case (Johnston et al., 2001). Even if the RMS value is higher than 1, RMSSE (Root Mean Square Standardized) is very close to 1, being values that indicate a good prediction model (Robinson & Metternicht, 2006).

Another parameter can be considered is the ratio Nugget/sill, in this model it is equal to 3.47% (with Nugget = 1.18 and sill = 33.94); which means that the stocking density variable has a strong spatial dependency. When the ratio is between 25% and 75%, the variable has moderate spatial dependency, otherwise it will be a weak dependency (Zheng et al., 2009).

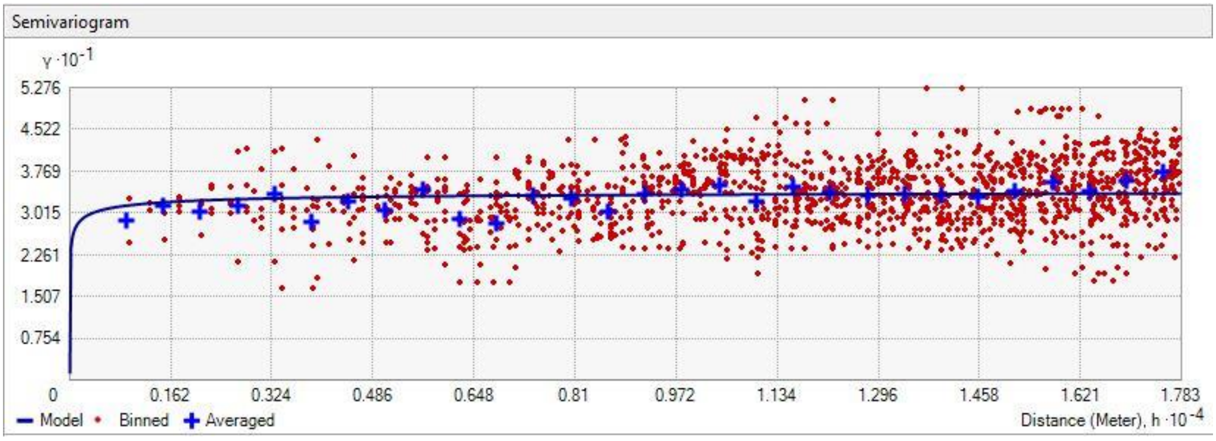

Figure 18: Representation of the semivariogram obtained from the best simulation

The figure above shows that beyond a distance of 1911m (value of the range), there is no more correlation to the distance of the stables, in the similarity of points.

Table 4: Results of prediction errors in semivariogram modelling

Parameter	Value
Lag size	594.2
Number of lags	30
Mean error	0.00029
Root mean square	6.223
Mean standardized error	0.00005
Root mean square standardized	1.089
Average standard error	5.714

The Ordinary kriging algorithm tends to be better than IDW (inverse distance weighted) although more complex (Robinson & Metternicht, 2006). It is common practice to use cross-validation to validate the accuracy of an interpolation (Voltz and Webster, 1990). Cross-validation is achieved by eliminating information, generally one observation at a time, estimating the value at that location with the remaining data and then computing the difference between the actual and estimated value for each data location (Davis, 1987). The Figure 19 shows obviously the difference between the two interpolation methods, kriging has lowest ME and RMS thus a better spatial interpolation.

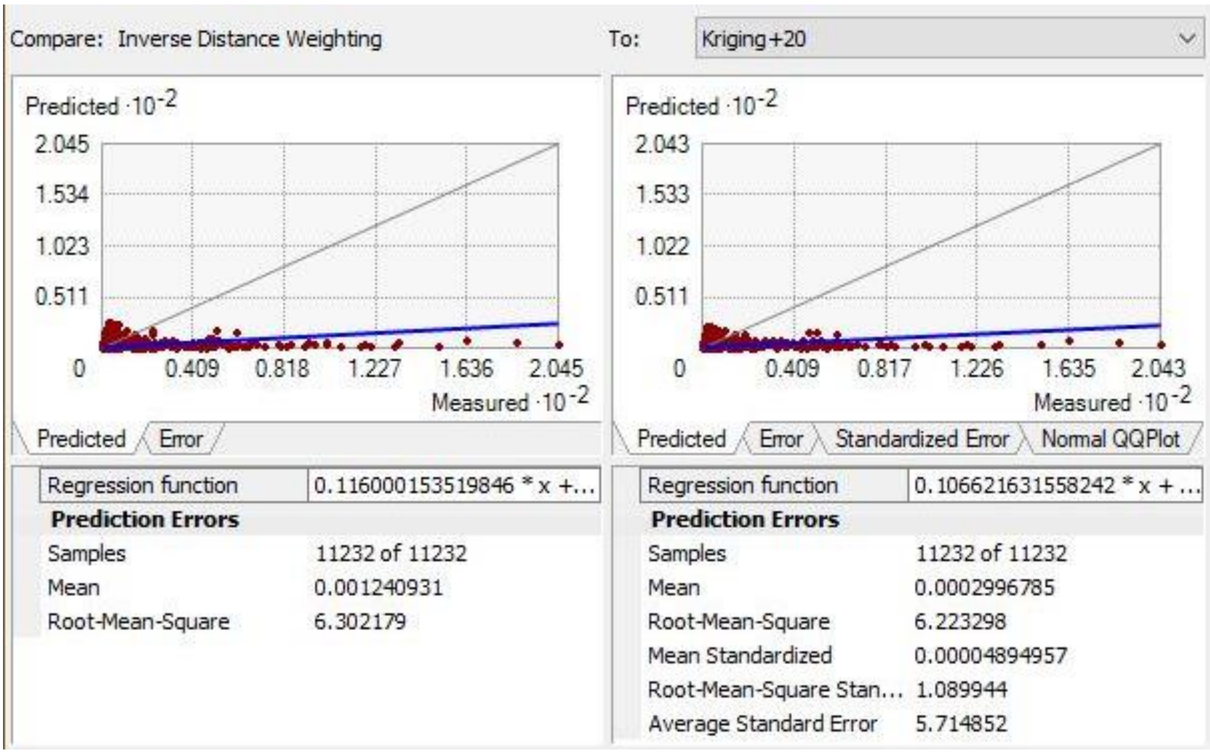

Figure 19: Comparison between IDW and kriging with cross validation

After using the spatial interpolation using kriging we proceed to rasterization of the output, then to divide it into 0.87 as mentioned before in methodology. The raster obtained is presented below (Figure 20):

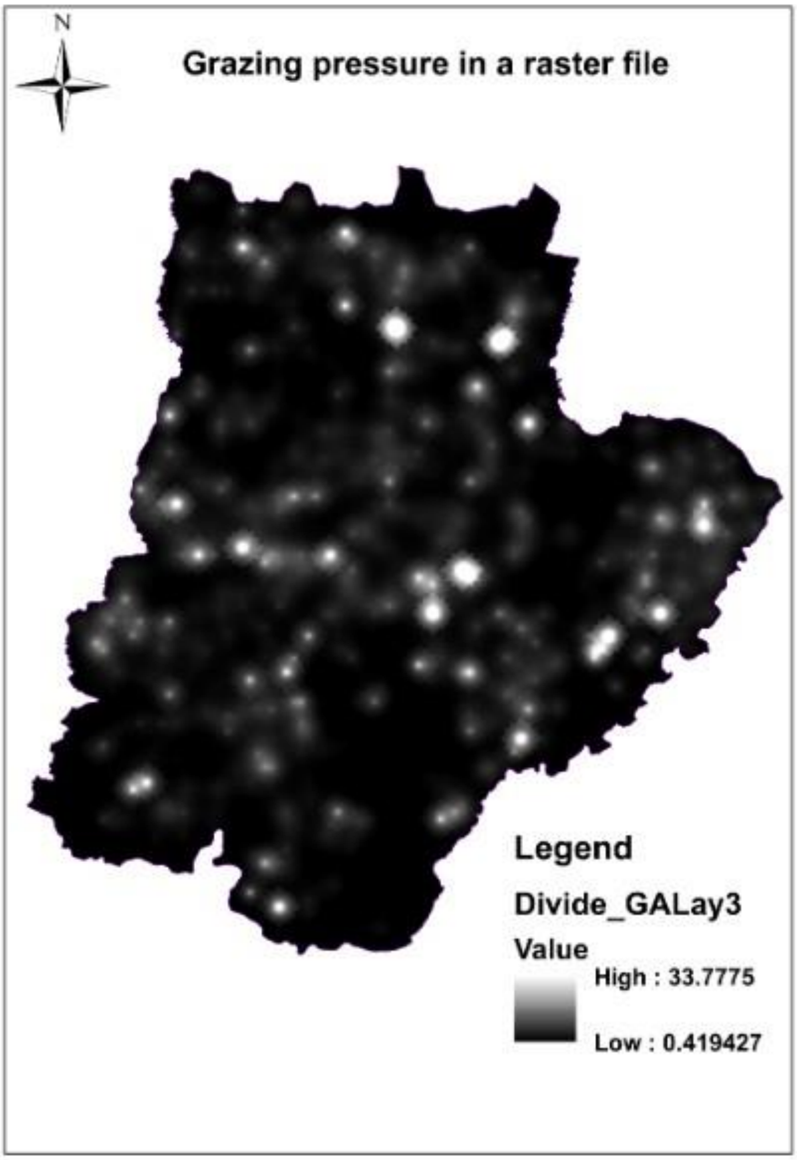

Figure 20: Rasterization of the prediction map –resolution = 25m

4.4 Evaluating the grazing pressure

As presented in the Figure 21, we reclassify the LUC classes to obtain a boolean map of the grazed (permanent crops, annual crops, shrublands, grasslands, grazed forests) and ungrazed areas (water, ungrazed forests and urban). The next step consist in combining the two information obtained from the raster of kriging and the raster map of grazed and ungrazed areas to finally obtain the grazing pressure map (Figure 21).

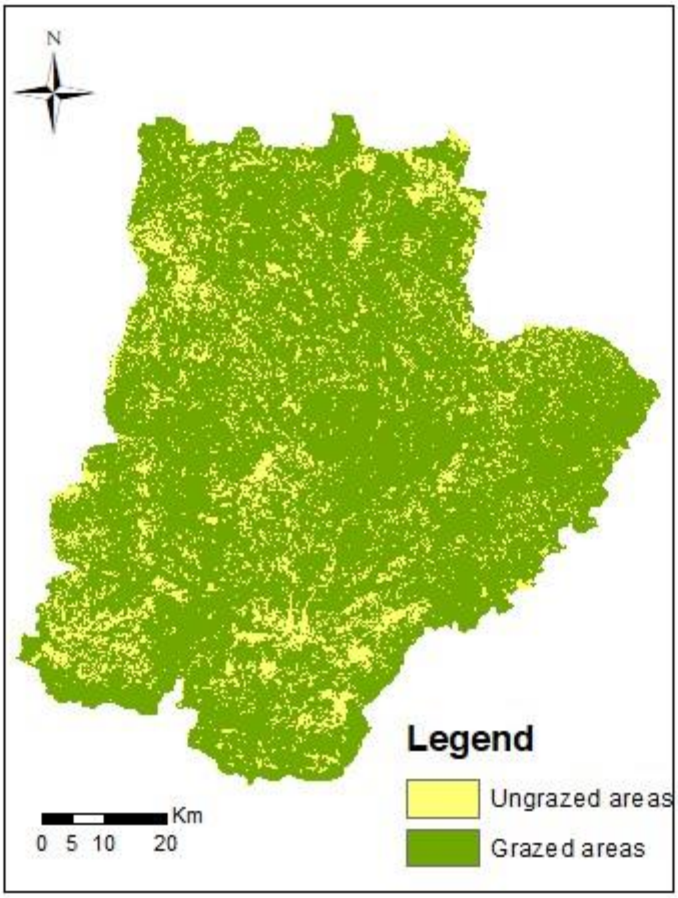

Figure 21: Raster of LUC map according to grazing criteria

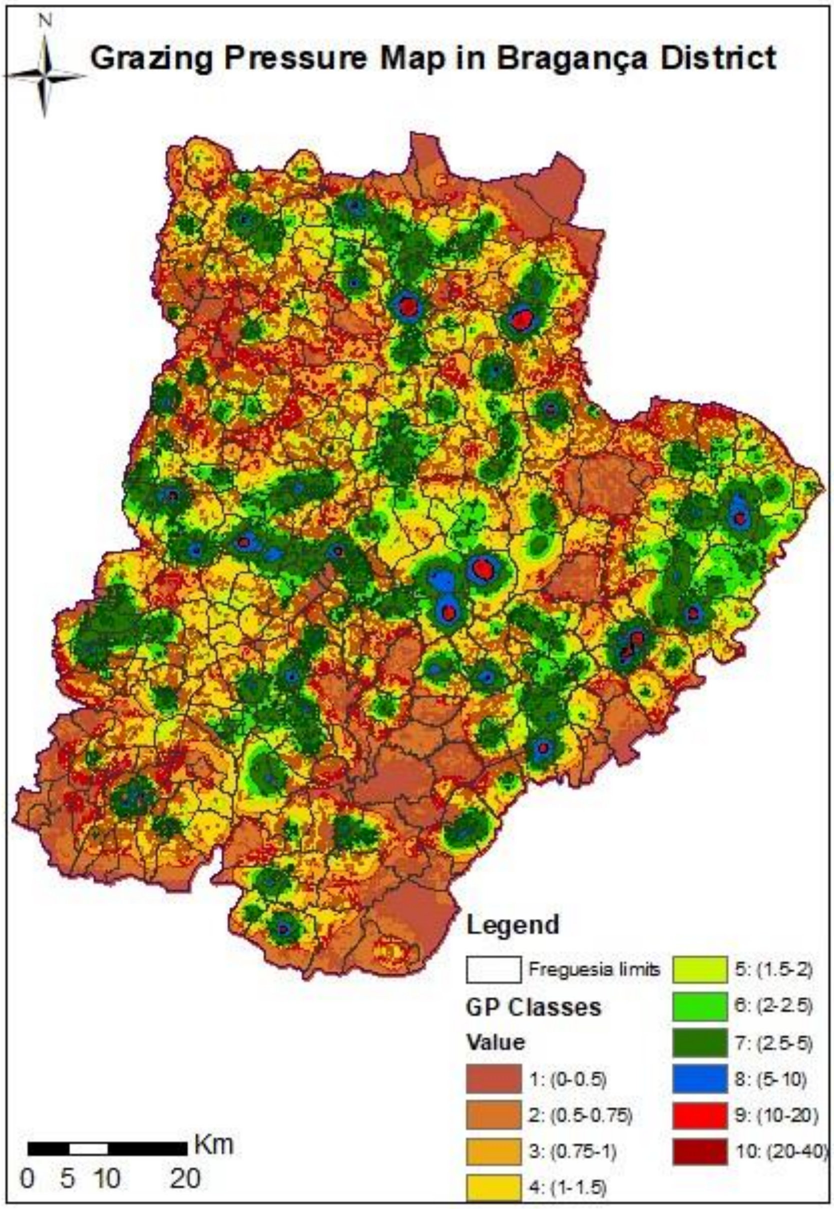

Figure 22: Grazing pressure map of Bragança region

To discuss the results obtained, we perform the figures below to make comparison of the availability and the grazing pressure occurring in the study area;

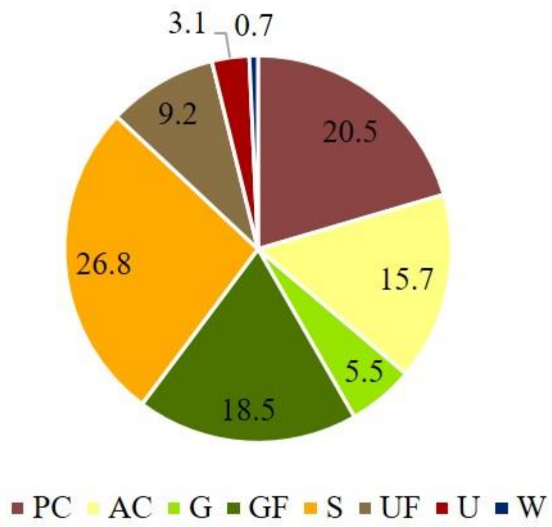

Figure 23: Frequencies (%) of Land use and cover classes covering Bragança region

The Figure 23 sheds light on the contribution of different LUC classes in the land of Bragança region. The study area shows a dense spatial coverage of shrublands with 26.8%, followed by permanent crops (20.5%), then grazed forests (18.5%). Annual crops with 15.7% have also a significant territorial contribution (more than 100,000ha). For the remaining classes (ungrazed forests, grasslands, urban and water bodies) represent less than 100,000 ha. Ungrazed forests (9.2%) represent high proportion in comparison with grasslands (5.5%), noting that ungrazed areas (Ungrazed forests, Urban, Water bodies) represents 13% from all the land. Therefore, the prediction map displaying the grazing pressures will discount that area since it isn't reached by ruminants. The highest extent of shrublands in Bragança region can be justified by the progressive encroachment of shrubs in favour of grasslands and rangelands as a consequence of undergrazing and the lack of influence of goats within the grazing system (Fernández et al., 2017).

Many centuries of intense human activity have led to progressive reduction of the original dense forests (deciduous), converted into agricultural land such as PC (permanent crops) and AC (annual crops), or settlement of the current cities (Barbero et al., 1990).

In the same context, although grasslands occupy small proportion, it tends to evolve as a prospective to promote pastures to feed domestic animals (Porqueddu et al., 2016). Grasslands in Portugal are dominant mostly in the southern half of the country (Van doorn, 2007 quoted by Pulido-Fernández et al., 2018).

The Figure 24 illustrates the contribution of each LUC class for the grazing pressure (GP) obtained.

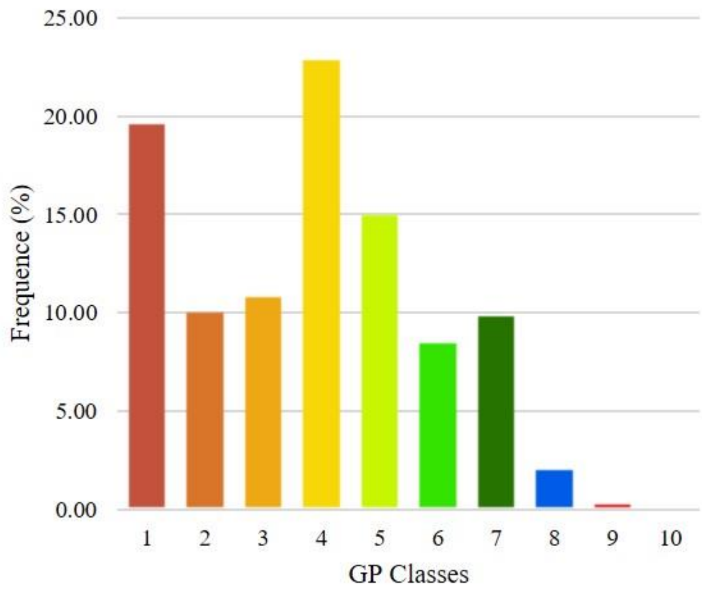

Figure 24: Frequencies (%) of grazing pressure classes

Table 5: Classification of grazing pressure in 10 classes

Class	1	2	3	4	5	6	7	8	9	10
GP (sheep or goat/ha)	<0.5	0.5-0.75	0.75-1	1-1.5	1.5-2	2-2.5	2.5-5	5-10	10-20	20-40

As the graph shows, the class 4, with 1-1.5 ruminant/ha, is the predominant class, followed by the lowest class 1, with less than 0.5 ruminant/ha, then comes the class 5 (1.5-2) with a proportion of 15%. The classes 2 and 3 (between 0.5 and 1), represents more than 20 %, contrary to the class 6 (between 2 and 2.5 ruminants/ha) represents less than 20%. The two remaining classes, with more than 20 sheep or goat per hectare, contribute with less than 3% in all the GP.

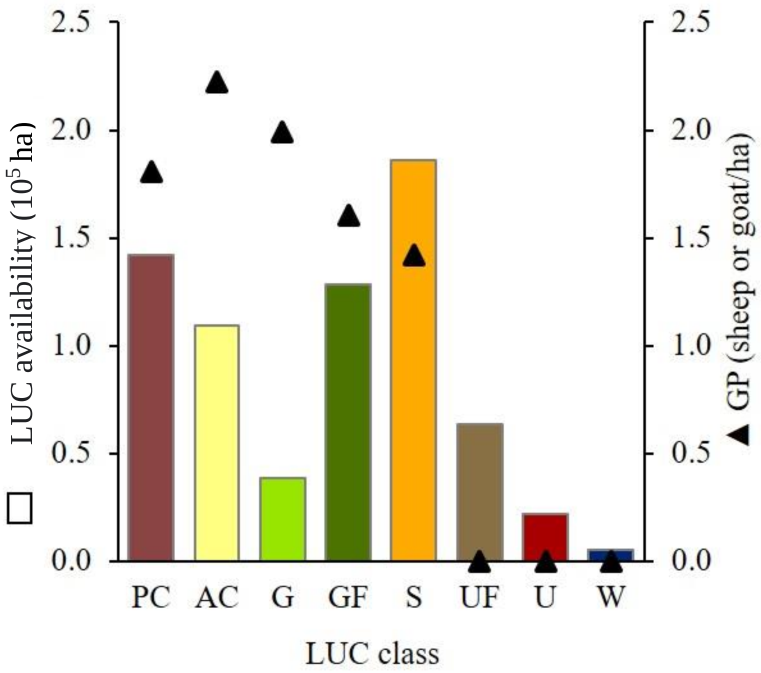

Figure 25: Histogram of LUC availability and its related grazing pressure

PC: Permanent crops, AC: Annual crops, G: Grasslands, GF: Grazed forests, S: Shrublands, UF: Ungrazed forests, U: Urban, W: Water bodies

The target from this work is to evaluate the distribution of the grazing pressure in each land use and cover class. Figure 25 make comparison between LUC availability and the grazing pressure exerted on it. The higher grazing pressure is exerted on annual crops, then on the grasslands, followed by permanent crops, then grazed forest and finally shrublands, while the GP shows zero value in ungrazed forests, water and urban classes. As we can notice in the graph, combining the availability and consumption of the land-use classes, comes up with deducing that grazing pressure in most of areas exceed their availability except for shrublands which are represented with the highest proportion.

In grasslands, there is a high grazing pressure although their low availability; in fact, sheep preferentially select forbs (i.e., broad-leaved plants) during certain times of the year (George et al., 2016), which explain the GP exerted on grasslands. In addition, grasslands are often devoted strictly to cattle.

The agrarian LUC matrix and woodland matrix represent only small difference of availability and consumption. Shrublands are available in a good quantity but small ruminants don’t have preferences for them, contrary to grasslands which are highly grazed but not enough available for grazing.

Diets of sheep and goats may differ, that explains the variability in grazing pressure of the different LUC classes; Castro & Fernández Núñez, (2016) reported in his study made in the northeast Portugal, that herbaceous plants including annual crops (i.e. cereals) and grasses are the most dominant in the sheep diet and with a lower proportion in goats' diet. Shrubs followed by tree species -belonging to permanent crops class- are highly preferred by goats than sheep.

By performing a qualitative analysis of our study flock, they may be a difference in its composition, where sheep represent 88.6% and goat 11.4%; for that we performed information about each preferred diet of each specie (Table 6 below).

Table 6: Ruminants' preferences (%) for each LUC class

	PC	**AC**	**G**	**GF**	**S**	**Flock proportion**
Sheep	19	36	29	10	6	88.58%
Goats	1	15	9	21	54	11.42%
Total preferences	16.9	33.6	26.7	11.3	11.5	

We can conclude that the preferences of combined ruminants (sheep and goats), is consistent with the distribution of their grazing pressure by LUC classes, following progressively the sequence below: AC (annual crops), G (grasslands), PC (permanent crops), and for GF (grazed forests) and S (shrublands), showing ruminants almost the same percentage of preference, differently for grazing pressure which is higher in GF than in S.

5 Conclusion and recommendation

This study made in Bragança region using GIS and available database allows to have an overall view regarding the land-use and cover availability in one hand, and the grazing pressure exerted by sheep and goats in the other hand. The classification of land use and cover is based on an aggregation of detailed subclasses from the recent land use and cover map (COS2018), coming out with 13% of ungrazed classes and 87% of grazed classes. Stocking densities, obtained from the buffer zones surrounding the sheepfolds and goat farms, allow to have a spatial distribution of grazing pressure. The quality of spatial interpolation has been tested by using two methods: ordinary kriging and inverse distance weighted. The cross validation exhibiting predicted errors of each method shows that kriging is more efficient for the spatial interpolation of stocking densities. Besides kriging measures the degree of dissimilarity between locations and also the correlation that depends on the distance between the points, through semivariography notion. In this context, spatial interpolation is based on the application of rules of variography, the best interpolator being the one that minimises prediction errors through empirical processes. The combination of the predicted map generated and the land use and cover map enable to have classes of grazing pressures. A first analysis is based on the cognizance of grazing pressure exerted in each class. For more accuracy, a second analysis take place; we analyse the grazing pressures and the preferences of small ruminants for each LUC class taking into account the proportion of sheep and goats. We found out that the ranking of LUC classes is the same on both: the grazing pressure and the animals' preferences, except for grazed forests and shrublands which have almost the same animals' preferences but not the same grazing pressure. The results show that the highest grazing pressure is applied on annual crops (2.22 sheep or goat/ ha), followed by grasslands (1.99 sheep or goat/ ha), then permanent crops (1.81 sheep or goat/ ha), grazed forests (1.61 sheep or goat/ ha) and finally shrublands (1.42 sheep or goat/ ha). Besides the most common grazing pressure in Bragança region is low, about 1-1.5 sheep or goat/ ha. Regarding the availability of LUC, shrublands represent the largest percentage coverage of the study area.

Concerning the severity and frequency of wildfires, we intend to analyse the effect of sheep and goat grazing in order to reduce the accumulation of biomass and consequently reduce the risk of fire, particularly in those land cover classes most prone to fire, for example forest and shrublands.

Thus, the spatial abundance of shrublands that can be implicated in wildfires, represents a major risk both to the human population and to flora and fauna. In this perspective, GP modelling and mapping is a powerful tool that can be used to assess the implementation of herding programmes aimed at reducing fire hazards, both on a parish and regional scale.

Management of grazing patterns in a landscape is a task involving judicious use of means to accomplish the best management. As a recommendation for this work, it would be relevant to have updated data concerning livestock headcounts, nevertheless, this model could be applied whatever the temporal and geographical circumstances as long as the database is available. Also, another way of classification of land use and cover can be performed with satellite images. Besides, there is another factor that could be interesting for such a study; it is water proximity from the farms, it can have a correlation with livestock patterns and also can be implemented in spatial analyses. Furthermore, interpolation of spatial data can be tested by open source programming languages such as R.

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Annexes

Annex I: Nomenclature of the land use and cover map of Mainland Portugal (DGT, 2019)

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