Chapter

Sheep Grazing Management in the Mountain Region: Serra da Estrela, Portugal

António Monteiro, José Costa, Fernando Esteves and Sérgio Santos

Abstract

Semi-natural Mediterranean pastures are an important resource in traditional systems of land use, namely in the Serra da Estrela region, located in the centre of mainland Portugal, where livestock activity is performed, mostly based in the dairy sheep farming. It is a region of rugged and mountainous relief, composed of shrub and herbaceous strata, usually associated with the sheep diet while they are grazing. These pastures take on some typologies, mainly in the mountain areas, including meadows, mesophille perennial *Nardus* grasslands and other perennial pastures of high ecological and scenic value. The floristic composition is predominantly composed of grasses (Poaceae), and legume (Fabaceae) species. The implementation of adequate cultivation techniques for the pasture management allows an increase in its productivity and nutritional value, resulting in increased stocking rate and reduced supplementation needs. In addition, these techniques promote the maintenance of biodiversity and landscape mosaic supporting the environment programmatic indications of the Common Agricultural Policy. Thus, the characteristics, potentialities and management practices of grasslands in the Serra da Estrela region are described, based on a literature review. This chapter aims to provide useful information, to the farmers who intend to make their pastures management more efficient while promoting environmental sustainability.

Keywords: Serra da Estrela region, sheep farming, perennial pastures, grazing management, nutritional value, sustainability

1. Introduction

In the central region of mainland Portugal, mainly in the valleys embedded in the Serra da Estrela massif [1], the traditional management of native dairy sheep (**Figure 1**) based on the use of natural and semi-natural grasslands, gives their products a strong identity and an appreciable quality, while contributing to regional development and the conservation of valuable mountain ecosystems.

Serra da Estrela is a region of rugged and mountainous relief [2], composed of shrub and herbaceous strata, with peculiar soil-climatic conditions [3]. It is

Figure 1.
Native breed of dairy sheep "Bordaleira serra da Estrela" *grazing.*

characterized by hot and dry summers, generally cold and long winters and with some inter-annual and inter-monthly precipitation irregularity [4]. The soils are mostly of granite or schist origin, with low pH and low fertility, especially based on low organic matter levels [2].

The main types of herbaceous formations that occur in Serra da Estrela mountain grasslands include permanent semi-natural meadows ("lameiros"), mesophille perennial *Nardus* grasslands, available in areas of higher altitude and high oligotrophy and other perennial pastures of high ecological and scenic value [5].

Permanent semi-natural meadows play an important role in the feed regime of dairy sheep while they are grazing. *Lameiros* are usually characterized by their water availability [6] and for their grazing management regime as pasture, forage and hay meadows, where Poaceae and Fabaceae species of some nutritional value predominate, namely, *Dactylis glomerata*, *Lolium perenne*, *Festuca arundinacea*, *Holcus lanatus, Trifolium pratense* and *Trifolium repens*, tolerant to soil and climatic conditions [7].

The management of these meadows consists of grazing throughout the year, except in the spring to allow a cut for hay production, being the feeding basis of the native breeds [8]. It is precisely the alternation of cutting with grazing, as well as the practice of cleaning and meticulous distribution of irrigation water, that has contributed to its maintenance and sustainability [7]. However, the trend towards depopulation of mountain regions, coupled with a scenario of increasing limitation of water resources, may endanger the sustainability of semi-natural mountain grasslands.

Beyond its economic relevance for livestock grazing and hay production, it is of huge interest to emphasize the great importance of mountain meadows for the essential services they perform, such as soil improvement and conservation, increased infiltration, drainage and water availability, soil protection against erosion and carbon sequestration [9]. Besides that, meadows are recognized as a protected habitat particularly of rare plant and fauna species and contribute to the beauty of the landscape mosaic [10].

Thus, the attributes, potential and practices of pasture management in Serra da Estrela are described, based on a bibliographic review. This chapter aims to provide useful information, especially for farmers who want to make pasture management more efficient and promote environmental sustainability in this region.

2. Geomorphologic and climatic characteristics of the Serra da Estrela mountain

Serra da Estrela is the highest mountain massif in mainland Portugal (40° 20' N, 7° 35' W, 1993 m ASL) and is part of the Iberian Central Cordillera [1]. It is covered by a biogeographical unit known as the Estrelensean Sector (Carpetan-Leonese subprovince) [4] aligned in a NE–SW direction (**Figure 2**) [1]. Its relief is characterized by the widespread occurrence of uplifted planation surfaces, the majority of which are between 600 and 900 m in altitude, dissected by deep river valleys, sometimes interrupted by larger tectonic basins [2].

Acid[1] and phosphorus-poor palaeozoic schists intruded by variscan granitoids are the prevailing lithological types in Serra da Estrela mountain [2]. Phytogeographic elements suggest that the Serra da Estrela is in the transition between the Mediterranean and Atlantic influence [4]. Its very particular geographical position, in conjunction with the territory orography, influences the local climate characteristics and allows the existence of several bioclimatic stages [3].

Despite widespread perceptions of more recent changes in climate behavior patterns, the warmest month is July and the coldest is January. The average annual temperature is lower than 7°C mostly in the plateau areas [12].

During the summer, there are usually periods of a few consecutive days with high temperatures. Climate data show that it has been a trend towards an increasing frequency of days with very high temperatures, as well as the occurrence of several heat waves in last years [13].

Average precipitation values vary between 1000 mm in the territories of the Mondego valley, Seia and Gouveia and values above 2500 mm per year at the highest altitudes of the central plateau. Despite its irregular pattern, rainfall occurs mainly between November and March [14]. The western side of the mountain presents a larger number of days with rainfall, but a slightly lower total amount than the eastern part, which in turn shows a smaller number of days with rain [15]. There is a large snowfall irregularity and rarely lasts more than a few weeks per year, especially below 1700 m. Wind regimes are complex and show large spatial variations. The more frequent directions are west and northwest [16].

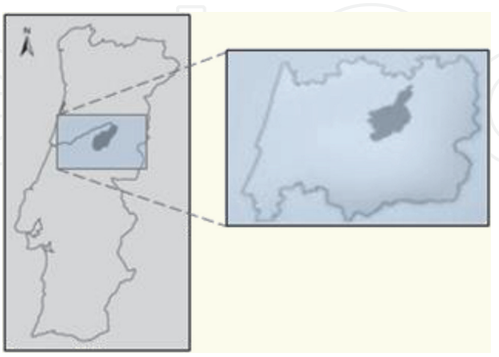

Figure 2.
Geographic location of mountain region—Serra da Estrela, Portugal.

[1] Soil acidity, which is frequent in mountainous regions, is one of the main limiting factors in the development of altitude pastures. The accentuated acidity is mainly due to the constant base washing of the soil profile as a result of the high levels of precipitation associated with the relief effect [11].

3. Grasslands in Serra da Estrela mountain region

Mountain grasslands are semi-natural permanent meadows dominated by spontaneous or sub-spontaneous herbaceous plants, with the predominance of poaceae species [7, 17]. They are typified by extensive farming using traditional breeds of sheep [9] and represent a valuable resource in the livestock farming activity of the region [5]. Their management is very different due to the high species richness and heterogeneous locations [18]. Semi-natural grasslands require continued grazing and/or mowing for their maintenance [9, 19] and have a relatively low productivity compared with intensively managed grasslands [20]. Their productivity is low, but they offer a number of services valued by society [21].

In fact, mountain grasslands of Serra da Estrela (**Figure 3**) are an important aspect of landscape and management and of great ecological value [5, 18], being part of the most protected ecosystem in Europe. They are recognized as key habitats for maintaining biodiversity in agricultural landscapes [20] and also an extremely important carbon store [22].

Mountain pastures on private land are often subject to mixed use of mowing and trampling. Mowing is important for getting hay in late spring or early summer depending on its location [7, 17]. In territories above 1000 m altitude and generally in Common lands (*Baldios*), pastures are used only for grazing, in many cases just in the summer season, with lower intensities of use and, consequently, with invasion of shrub species [21].

Mountain meadows growth is strongly conditioned by environmental conditions, in particular by altitude, slope, exposure, soil and inter-annual climate variation, and also due to the management conditions, such as irrigation, fertilization and utilization management (grazing and mowing) [7].

The main types of herbaceous formations that occur in Serra da Estrela mountain grasslands include permanent semi-natural meadows ("lameiros"), mesophille perennial *Nardus* grasslands and other perennial pastures, which will be described below [5].

3.1 Mountain semi-natural meadows ("lameiros") and its floristic composition

Mountain semi-natural meadows ("lameiros") are one of the most characteristic elements of the mountain landscapes of northern and central Portugal [10], namely in the Serra da Estrela, dominated by complexes of spontaneous and sub-

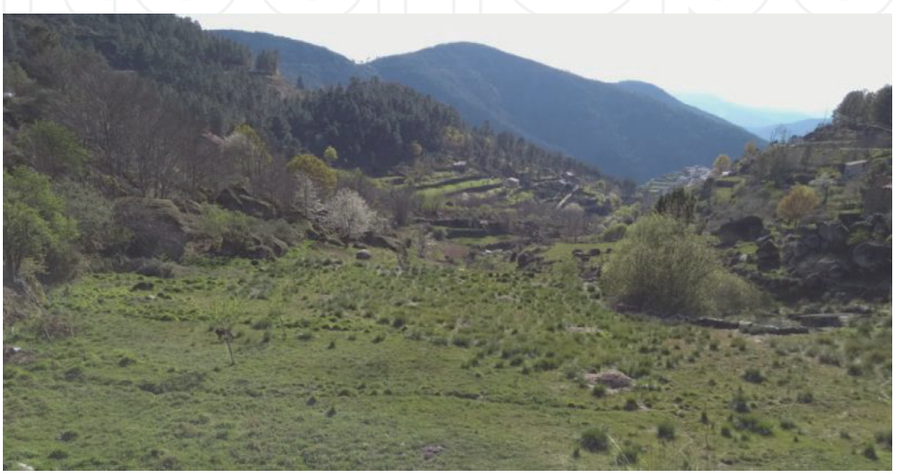

Figure 3.
Mountain grasslands in Louriga, Serra da Estrela.

spontaneous herbaceous vegetation whose composition varies in place and time as a function of soil and climatic conditions and the duration and grazing or mowing intensity, chemical or organic fertilization or the irrigation system [23].

They are usually found in places with good water availability and fine-textured soils with high levels of organic matter [6]. Mountain meadows are not a result of deliberate sowing of improved species and are not subjected to practices such as pesticide application or soil tillage [7].

"Lameiros" are usually characterized by their water availability, as **irrigated meadows** located along permanent watercourses, **imperfect irrigated meadows** when located along non-permanent or reduced low-flow watercourses and **non-irrigated meadows** (or *lameiros de secadal*), next to temporary watercourses without water for irrigation and usually located on the highest altitude plateaus [7, 17].

The grazing management regime in the meadows is generally characterized as:

- **Pasture meadows**, also known as "pastigueiros," whenever its production is used exclusively for grazing [7, 17]. They occupy non-irrigated plateau areas, therefore are less productive, but can sustain livestock during spring and early summer [24];

- **Forage meadows**, usually irrigated at least for some part of the year, are more productive than "pastigueiros" and made up of a larger number of nutritious species. They are also used in a mixed regime (mowing and grazing), excluding grazing in the spring [24] so that the grass grows and can be cut for hay in early summer to be reserved for consumption during the following winter [7, 17].

- **Hay meadows**, also known as "segadeiros" or cutting meadows, are the most productive pastures, irrigated all year round, fertilized and cut exclusively during the summer, and the grass is immediately consumed by the animals [7, 17, 24].

In meadows with a large animal density, the replacement of *Juncus effusus* and *J. acutiflorus* with *J. inflexus* is often observed, accompanied by several other nitrophilic species such as *Agrostis stolonifera*, *Potentilla reptans*, *Mentha suaveolens* and *Ranunculus repens*. In fact, these are low-yielding species, produce poor-quality hay and avoided by ruminants. The most productive and palatable species include *Holcus lanatus*, *Cynosurus cristatus*, *Festuca arundinacea subsp. arundinacea*, *Plantago lanceolata*, *Trifolium pratense* and *T. repens* (**Table 1**). The drier parts of the meadows often show an impoverished community of *Arrhenatherum elatius subsp. bulbosum* or communities of *Agrostis castellana* in even drier soils [23].

Beyond its economic relevance for livestock grazing and hay production, meadows are recognized as a protected habitat particularly of rare plant and fauna species. "Lameiros" also contribute to the beauty of the landscape mosaic, thus with impacts on tourism, particularly relative to nature trails [10].

3.1.1 Meadows management: cultural practices

3.1.1.1 Grazing and grass/hay management

Sheep grazing controls the development of various herbaceous species on the meadows, acting as an agent for the pasture maintenance [25, 26]. Grazing occurs in spring due to the higher precocity of its vegetative development in relation to the

	Types of mountain semi-natural meadows				
	Irrigated meadows	**Imperfect irrigated meadows**	**Non-irrigated meadows**	**Pasture meadows**	**Hay meadows**
Species	*Holcus lanatus*	**Floristic composition close to irrigated or non-irrigated meadows, depending on the greater or lesser availability of water**	*Agrostis castellana*	*Rumex crispus*	*Lolium perenne*
	Plantago lanceolata		*Agrostis x fouilladei*	*Rumex obtusifolius*	*Dactylis glomerata*
	Cynosurus cristatus		*Trifolium dubium*	*Rumex conglomeratus*	*Trifolium repens*
	Hypochaeris radicata		*Gaudinia fragilis*	*Mentha suaveolens*	*Trifolium pratense*
	Poa trivialis		*Arrhenatherum elatius* subsp. *bulbosum*	*Brachypodium rupestre*	*Holcus lanatus*
	Dactylis glomerata				*Ranunculus repens*
	Trifolium pratense				*Plantago lanceolata*
	Trifolium repens				*Glyceria declinata*
Notes				**Abundance of species rejected by animals**	**Have the largest amounts of plants of great nutritional value**

Table 1.
Floristic composition in meadows with different water and use regimes—Adapted from [7].

common lands ("baldios"), thus ensuring an adequate transition between feeding of herds with hay in winter and with grazing the common lands in the summer.

When the grass is ready to be grazed in the common lands, access to the meadows is limited in order to allow the development of the vegetation to obtain hay [8]. Hay cutting time should coincide as closely as possible with the dominant grass spike in the meadows to obtain hay with good nutritional value [7].

When the common lands vegetation becomes scarce and very dry in the late summer and, at the same time, there occurs the regrowth of vegetation in the meadows after hay cutting, grazing is allowed again until mid or late autumn [8] depending on the environmental and growing conditions of the grass [21].

The absence of the flocks grazing results in loss of biodiversity, due to changes in vegetation development [25]. Similarly, hay cutting also acts as a maintenance agent favouring the development of the most desirable plants and the persistence of rare plant species. Haying has a very positive effect on yield, both on hay and pasture, which is less significant with late haying [17].

3.1.1.2 Water regime

Irrigation is practised in meadows throughout the year whenever water is available although its functionality changes seasonally. During the summer (usually, July to September), it aims to meet the water needs of vegetation and, during the winter period, provides a favourable thermal balance at the grass's micro-climate level ("lima" watering) [24].

The meadows irrigation is made by surface run-off using a system in which the run-off water concentrated in water lines is diverted to small slope channels from where it flows over the permanent pastures [24, 27, 28].

Water flowing over pasture is a traditional practice of winter irrigation made by a continuous flowing of a thin layer of water ("lima") covering the entire soil surface, to prevent frost damage [29] and to allow the rapid resumption of vegetation development during the spring [30]. Especially at night, irrigation water is relatively hotter than soil, pasture and air temperature, so the effect of frost is attenuated [31].

If water availability is not enough to guarantee this kind of irrigation for a relatively long period of frost, it is preferable to not irrigate, so as to avoid freezing of water in the soil upper layers causing damages to the plants root system, a phenomenon that is locally referred to as "descalçamento" [24].

3.1.1.3 Fertilization

Fertilizer application is a cultural technique with a positive effect on hay and pasture productivity [29, 30]. Studies by several authors show the positive effect of this cultural technique on the mountain meadows yield [30, 32, 33].

Traditional fertilization relies essentially on grazing animal waste and run-off "waters" from where they occur. Animal droppings are the main source of nutrients in mountain pastures and can reach 100 kg of nitrogen, 90 kg of potassium and 9 kg of phosphorus per hectare in 365 days of grazing [7].

Nitrogen fertilizers are indicated as those that lead to greater production increases and contribute more to the evolution of pasture composition, with repercussions on dry matter (DM) production [7].

3.1.1.4 Weed control

In meadows, the main problems with weeds are fetuses, brambles and other weeds rejected by grazing animals (low-palatability plants).

These weeds' incidence is generally associated with poor management of grass use. Its control is generally made by means of a cleaning cut which, at the same time, enhances the growth of more palatable species, correcting or nullifying the effects of a less efficient use [7]. Controlled fire use is used as a cleaning technique in the continuous weed patches.

The clearing of furrows, waterline banks is also a cultural operation with a positive effect on the meadows productivity, as it favors the conditions for water conduction and, consequently, the homogeneity of its distribution. This operation is normally carried out during the winter period by farmers and shepherds [34].

3.1.1.5 Pasture yield

The practice of rotational and rationed grazing by conditioning the number of grazing animals, per unit area and grazing time, avoids the under-utilization of "lameiros" in summer, resorting to the use of fences or regular displacement of animals between plots [7].

The yields can vary from 4 to 6 tons of dry matter (DM) per hectare (ha) per year, up to 12 tons DM/ha/year, which corresponds, respectively, to less than 1 livestock unit (LSU)/ha and more than 2 LSU/ha [7].

These differences in pasture production are related to the availability of water, the type of vegetation, the irrigation management and also the geographical

location. The best returns and economic results are obtained when a community management is adopted as opposed to the individual management of semi-natural meadows [35].

3.2 *Cervunais* and other perennial pastures

3.2.1 Cervunais

This particular ecosystem in Serra da Estrela, named "*cervunal,*" is characterized by the dominance of *Nardus stricta* L. (Poaceae), and involves 10.000 ha of a biogenetic reservation (DL n° 140/99, 24th April—Appendix B-1, 6230) within the Natural Park of Serra da Estrela (NPSE) [36].

Cervunais occur in areas of higher altitude (above 1600 m) and high oligotrophy. They are well adapted to winter cold and also to poor, acidic, often moist and poorly drained soils and are usually grazed by sheep and not submitted to mowing [5]. Due to their late development, *Cervunais* are an important resource for sheep feeding during late spring/early summer, playing an important role in the local economy, often arising from the Serra da Estrela cheese production system [37].

Their maintenance is clearly dependent on the correct management of grazing, which is fundamental in controlling invasion by woody species. At present, grazing management is in decline and the woody species are invading some of the grassland. The greater amount of combustible material in the woody plants has the potential to increase the temperature of fires to damaging levels, even in wet areas, compared to the fires by shepherds on the grasslands [36].

Fire represents the main threat to the conservation of this type of grasslands and is associated with inadequate practices of land management and planning [38]. Severe fires over the last decade have transformed the high-altitude grassland biogenetic reserve in the Natural Park of Estrela Mountain (NPSE) of Portugal. The most remarkable change in the herbaceous vegetation after fire was the abrupt increase of *Festuca trichophylla* in the burnt area, to the detriment and abrupt decrease of *Nardus stricta* [36].

3.2.2 Other permanent highland pastures

Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*) are made up of tall grass, associated with deep and well-drained soil. Their maintenance promotes the infiltration of water in the soil, the regulation of nutrient levels, the lack of continuity of the forest mosaic and, consequently, the prevention of forest fires. These grasslands are dominated by the species *Arrhenatherum elatius* subsp. *bulbosum*, *Agrostis castellana* or *Festuca rothmaleri* [39].

Molinia meadows are associated with calcareous, peaty and loamy soils (*Molinion caeruleae*), including the juncal and juncal-meadows, dominated by *Juncus effusus* and/or *Juncus acutiflorus* which develop in deep and acidic soils conserving moisture during almost the whole year. They are usually near water lines, occupying the territory of riparian forests. Juncal and juncal-meadows are not fertilized and have reduced feed value for sheep [40].

Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea* are distinguished by the occupation of deep, well-drained, oligotrophic soils, including communities dominated by *Agrostis castellana*, which are frequent in non-irrigated meadows [41]. They also include perennial grasslands, usually dominated by heliophilous grasses such as *Arrhenatherum elatius subsp. baeticum*, *Agrostis castellana, Celtica gigantea* and *Festuca elegans* [38].

4. Grassland species management, chemical and nutritive values

4.1 *Dactylis glomerata*

On established pastures, cocksfoot (*Dactylis glomerata*) initiates growth early in the spring. Grazing should begin when growth reaches approximately 20 cm. A 28- to 35-day recovery period is recommended [41].

Winter grazing should be limited to 60% of annual growth. Autumn to early winter is the preferred time for sowing. Spring sowing may be an option in higher altitude areas, or areas with more reliable rainfall over late spring and summer [42].

Cocksfoot is capable of moderate to high levels of herbage production in well-managed, regularly fertilized pastures. Growth rates of 60–80 kg DM/ha/day are possible in autumn and spring under conditions of good moisture and temperature. In winter, production will commonly range from 5 to 20 kg DM/ha/day. The actual amount of herbage produced will be influenced by many factors, including altitude, soil texture, soil moisture and temperature [42].

The protein content declines with maturity. This high protein content is balanced by a fiber content that is often higher than that of other grasses (ryegrass and fescue) at the same stage of maturity [43].

Cocksfoot is highly palatable to livestock especially in the early part of the growing season [41] (**Table 2**).

4.2 *Festuca arundinacea*

Festuca arundinacea (tall fescue) is a perennial plant with large size and well adapted to a wide range of climates. Tolerant of various soil types, it has a better yield on deep and fertile soils. It is not compatible with ryegrass (*Lolium* spp.). Sowing is done in the fall, usually mixed with lucerne in irrigated meadows. Seed establishment is slow and grassland has a weak initial development [45]. It can be used for direct grazing, mowing, hay production, hay silage or silage. Growth begins in early spring and grazing should begin after the plants are at least 15 cm tall. The height of the stubble should be kept at 10 cm. Regrowth is favourable in cool spring and fall weather. The recommended rest period between grazing cycles is approximately 21–28 days. Frequent spring grazing cycles when plants are in the vegetative stage will help reduce alkaloid concentrations in animal diets if there is a symbiotic relation with endophyte organisms [41].

Tall fescue has high digestibility at the appearance of the first year and provides good-quality biomass with 14–15% protein content in dry matter [41] (**Table 3**).

	Composition (% DM)							Nutritive value				
Herbage	**DM (% as fed)**	**CP**	**CF**	**NDF**	**ADF**	**Lignin**	**Ash**	**OMD (%)**	**ED (%)**	**DE (MJ/kg DM)**	**ME (MJ/kg DM)**	**ND (%)**
Fresh	20.7	16.3	29.7	59.9	32.3	4.5	9.7	69.4	66.3	12.0	9.5	58.9
Dried	89.1	13.1	30.2	63.7	36.5	4.5	8.7	65.1	61.5	11.1	8.9	57.7

DM: Dry matter; CP: Crude protein; CF: Crude fiber; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; OMD: Organic matter digestibility; ED: Energy digestibility; DE: Digestible energy; ME: Metabolizable energy; ND: Nitrogen digestibility.

Table 2.
*Chemical composition and nutritive value of cocksfoot (*Dactylis glomerata*) [44].*

		Composition (% DM)						
Phenology	**DM (%)**	**CP**	**CF**	**NDF**	**ADF**	**NDF**	**Ash**	**OM**
Early flowering	83.4	15.0	30.7	65.1	39.9	4.6	—	83.4

DM: Dry matter; CP: Crude protein; CF: Crude fiber; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; OM: Organic matter.

Table 3.
*Chemical composition of tall fescue (*Festuca arundinacea*) [46].*

		Composition (% DM)						
Phenology	**DM (%)**	**CP**	**CF**	**NDF**	**ADF**	**NDF**	**Ash**	**OM**
Spikelet	21.0	15.0	26.8	56.8	30.2	3.8	—	84.7
Hay	80.0	22.1	19.6	41.9	29.6	4.9	—	91.6

DM: Dry matter; CP: Crude protein; CF: Crude fiber; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; OM: Organic matter.

Table 4.
*Chemical composition of perennial ryegrass (*Lolium perenne *L.) [46, 47].*

4.3 *Lolium perenne* L.

Lolium perenne L. (perennial ryegrass) (**Table 4**) is better adapted to the temperate climate of the Atlantic than to hot summers as they slow down its growth. It also prefers fertile, heavy and moist soil, slightly acidic pH—demanding in nitrogen.

Sowing is preferably made in the fall, with fast seed germination and crop establishment. It has regeneration speed and resistance to trampling. It can be mixed with red clover, white clover or hybrid ryegrass (*L. perenne*, *L. multiflorum*). Thus, when mixed with white clover, it produces about 12–14 t MS per ha/year.

Perennial ryegrass has high digestibility and protein content compared to other perennial grasses [45].

4.4 *Holcus lanatus*

Holcus lanatus occurs over a wide range of soil types, although it prefers a soil pH range of 5–7.5. It is found in hay meadow communities, poorly drained and waterlogged soils, and low-fertility and nutrient-rich soils, pastures and meadows. Although *H. lanatus* is adapted to growing in wet conditions, it can also survive moderate drought, but with a much reduced growth rate [48].

Normally, *H. lanatus* is not preferred by flocks as its hairy nature means it is less digestible than perennial ryegrass (*Lolium perenne*) [49]. The young shoots are promptly consumed by the flocks, the dry matter content is low, digestibility is good and the mineral composition is relatively high [48] (**Table 5**).

4.5 *Trifolium pratense*

Trifolium pratense (red clover) is sown in autumn or spring. It is a very productive plant, but demanding in humidity, phosphorus, potassium and other elements. It shows predominant growth in autumn-winter, is more suited to cutting than grazing, produces up to 5–6 cuts in the first year when sown in the fall and is used for mowing when pure and mainly for grazing in mixtures [45].

	Composition (% DM)							
Phenology	**DM (%)**	**CP**	**CF**	**NDF**	**ADF**	**NDF**	**Ash**	**OM**
Spikelet	28.7	6.3	34.2	71.5	41.0	5.6	—	91.1

DM: Dry matter; CP: Crude protein; CF: Crude fiber; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; OM: Organic matter.

Table 5.
Chemical composition of Holcus lanatus *[47].*

Red clover should be cut for hay when no more than 50% is in flower, when it has the optimal feeding value, with more than 14–15% protein. Mowing red clover later impairs its feeding value but also compromises the second cut, as young shoots already elongated may be removed during the first cutting [50].

Red clover is preferably grazed in spring. Grazing begins at the quarter to half-bloom stage. In spring and early summer, a rest period of 21–35 days is recommended. Regrowth is excellent in spring when temperatures are low and soil moisture is available, but poor later in the summer [41]. Its contribution to biomass production declines rapidly after the first 2–3 years under grazing [51] (**Table 6**).

4.6 *Trifolium repens*

White clover (*Trifolium repens*) is the most important forage legume for grazing, whether as a spontaneous component of natural or permanent pastures or sown in association with grasses such as perennial ryegrass (*Lolium perenne*) [51]. The inclusion of white clover (**Figure 4**) in mixed pasture (grass and legume) increases the feeding value of the pasture due to the high protein and organic matter (OM) digestibility of white clover [52].

White clover can withstand both continuous stocking and rotational grazing. In rotational grazing systems, stolons can regrow during rest periods, thereby increasing the white clover contribution to the stand. White clover cultivars should be chosen in accordance with the intended type of grazing: small leaf cultivars are best suited for continuous grazing by sheep, while large leaf types are best adapted to rotational grazing by sheep. In mixed swards, grazing should be heavy enough to prevent white clover being shaded and thus its decline [52] (**Table 7**).

4.7 *Plantago lanceolata*

Ribwort plantain (*Plantago lanceolata*) has a good production of dry matter, mainly in winter activity. In many environments, plantain produces similar amounts of perennial ryegrass fodder. A feature of plantain productivity is its rapid

	Composition (% DM)							Nutritive value				
Herbage	**DM (% as fed)**	**CP**	**CF**	**NDF**	**ADF**	**Lignin**	**Ash**	**OMD (%)**	**ED (%)**	**DE (MJ/kg DM)**	**ME (MJ/kg DM)**	**ND (%)**
Fresh	19.0	19.7	22.4	36.4	26.6	4.1	10.4	74.1	70.9	13.1	10.4	73.3
Dried	89.5	18.3	27.4	37.7	28.3	6.0	6.8	66.2	62.7	11.9	9.5	65.1

DM: Dry matter; CP: Crude protein; CF: Crude fiber; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; OMD: Organic matter digestibility; ED: Energy digestibility; DE: Digestible energy; ME: Metabolizable energy; ND: Nitrogen digestibility.

Table 6.
*Chemical composition and nutritive value of red clover (*Trifolium pratense*) [50].*

Figure 4.
*White clover (*Trifolium repens*).*

		Composition (% DM)						Nutritive value				
Herbage	**DM (% as fed)**	**CP**	**CF**	**NDF**	**ADF**	**Lignin**	**Ash**	**OMD (%)**	**ED (%)**	**DE (MJ/ kg DM)**	**ME (MJ/ kg DM)**	**ND (%)**
Fresh	16.8	24.9	19.6	27.5	22.1	3.9	11.3	80.9	77.3	14.2	11.1	82.2
Dried	82.7	22.7	23.4	29.4	28.8	3.5	12.3	65.1	61.6	10.7	8.4	69.3

DM: Dry matter; CP: Crude protein; CF: Crude fiber; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; OMD: Organic matter digestibility; ED: Energy digestibility; DE: Digestible energy; ME: Metabolizable energy; ND: Nitrogen digestibility.

Table 7.
*Chemical composition and nutritive value of white clover (*Trifolium repens*) [53].*

		Composition (% DM)						
Herbage	**DM (% as fed)**	**CP**	**CF**	**NDF**	**ADF**	**Lignin**	**Ash**	**OM**
Aerial part	15.7	20.4	13.6	41.1	29.3	13.8	12.4	—

DM: Dry matter; CP: Crude protein; CF: Crude fiber; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; OM: Organic matter.

Table 8.
Chemical composition of Plantago lanceolata *[55].*

response to moisture in autumn and also the rapid rumen degradation rates to improve dry matter intake [54].

In sheep grazing swards of white clover, ribwort plantain is fairly palatable. It proves to be suitable in combination with grass in swards to sustain growth in finishing lambs. It may also be recommended as an alternative to hay. However, compared to chicory (*Cichorium intybus*), it supports less live-weight gain and lower hot carcass weights [55] (**Table 8**).

5. Mountain grasslands as providers of an ecosystem service in Serra da Estrela

The sustainability depends on the multi-functional role of farming systems. Pastures are central part of these High Natural Value (HNV) systems [56].

Mediterranean mountain grasslands generate high levels of biodiversity and a range of other environmental services and amenities [57].

As the total area of grasslands has declined, particularly grasslands of high biodiversity, mountain areas are now among the last refuges of High Nature Value (HNV) grassland in Europe. Many traditionally managed mountain grasslands, which have developed under centuries of livestock grazing, are still species-rich compared with lowlands [18].

Well-managed grassland is associated with environmental advantages, including soil carbon sequestration, reduced soil erosion, and maintenance of ecosystem services associated with grasslands [9]. Shrub vegetation associated with these grasslands may contribute to the retention of soil water, a reduction in run-off and diminished soil erosion. Under climate changes scenarios that predict an increased frequency of high-intensity rainfall and more events leading to downstream flooding, the positive role of grasslands in mitigating such events may increase [57]. In tests conducted in different regions of the USA, with different soils and slopes varying between 2 and 16.5%, soil losses of 14.6–250.4 t ha^{-1} $year^{-1}$ were observed with monocultures of corn or cotton, while under the same conditions with pastures the losses amounted to only 0.01–0.70 t ha^{-1} $year^{-1}$ [58].

Extensive grazing is an essential tool for reducing fire risk on semi-natural pastures with shrubs and trees [21]. In the Mediterranean, grasslands have an important role in fire prevention. Rural abandonment is leading to the development and dominance of shrub formations, increasing vegetation fuel load and the hazards of fire. Frequently, extensive woodland and shrub vegetation are interrupted by areas of grassland or pasture, which act as effective barriers against propagation of wildfires. Maintenance of open grassland areas is thus essential to maintain landscape heterogeneity and a potential tool to mitigate the risks of wildfires [57]. In drier regions of Europe, and more widely with future climate change projections, wild fires will cause considerable loss of human life, environmental and property damage, and carbon release [21].

Threats are endangering the future of grasslands [59]. Although biodiversity is one of the most important ecosystem services provided by European semi-natural grasslands, agriculture remains as a driver of biodiversity loss, either through intensification and conversion of grassland to arable cropping, or land abandonment and loss of the traditional farming practices that have often generated species-rich habitats [18].

Appreciation and implementation of mechanisms for payment of environmental services, possibly similar to those already in uses in some forest land uses, may potentially contribute to the economic sustainability and future conservation of grasslands and their multifunctional role [57]. Recently, the Portuguese Carbon Fund has demonstrated interest in remunerating the farmers willing to control shrub encroachment at pastures through the use of non-invasive techniques that promote soil carbon sequestration [59].

The potential of pasture soils as carbon sinks, however, can be difficult to maintain in relation to predicted climate change scenarios, such as increased frequency of droughts and heat waves [57].

6. Conclusions

The sheep farming associated with permanent mountain pastures is of great significance for the sustainability and for the social and economic development of the local populations; so, the greater and better knowledge of the potential of this type of grasslands is of great relevance for the valorization of regions affected by desertification and less economically favoured.

Semi-natural pastures are an important source of feed for sheep grazing and when harvested as hay for the winter period in Serra da Estrela mountain. Therefore, it is necessary to optimize meadow management practices in order to meet their increasing needs for quality forages, as well as the knowing of adequate nutritive value of herbage, essential for a high rate of live-weight gain and overall sheep performance. In this sense, we suggest a guidance or training programmes that should be promoted to make farmers aware of how to improve and sustain pasture productivity.

Permanent mountain pastures are also of major importance for the conservation of floristic, faunistic and landscape biodiversity and other related ecosystem services such as carbon sequestration, soil conservation or as a factor in regulating the hydrological cycle. It is important that the traditional practices and the environmental management undertaken by farmers are not endangered by a desire of other stakeholders to transform the landscape, reducing farm capital.

Due to its ecological and economic value, it is also important to ensure the maintenance and improvement of these ecosystems in order to promote or increase its biodiversity. Encouraging the development of these land use will allow activities linked to livestock production and provide different externalities and ecosystems, thus according to the environment-supporting programmatic indications of the Common Agricultural Policy.

Furthermore, studies are necessary to fully understand the ecological and economical implications of reduction and changes in mountain grasslands in the context of a future rain decrease and global warming.

Finally, new researches should be carried out, such as the integrated processing and data analysis related to animal behavior and location, together with the analysis of the nutritional value of pasture species that will allow the creation of a decision support tool in the livestock management process.

Author details

António Monteiro[1,2*], José Costa[1], Fernando Esteves[1] and Sérgio Santos[1]

1 Agrarian Superior School, Polytechnic Institute of Viseu, Viseu, Portugal

2 CERNAS, Research Centre for Natural Resources, Environment and Society, Polytechnic Institute of Viseu, Polytechnic Campus, Viseu, Portugal

*Address all correspondence to: amonteiro@esav.ipv.pt

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