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Review

Livestock Management for the Delivery of Ecosystem Services in Fire-Prone Shrublands of Atlantic Iberia

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Abstract: In the northwest of the Iberian Peninsula, characterized by its humid climate, large rural areas are being abandoned, mostly in less-favoured areas covered by heathlands, which present a low nutritive quality for livestock production. The high combustibility of these shrublands is driving a high wildfire incidence with negative environmental and economic effects. In this review, some aspects on wildfire occurrence and the potential of grazing livestock to reduce woody phytomass and fire risk in heathland-dominated areas whilst maintaining quality production and preserving biodiversity are summarized. Heathlands may be partially improved—converted to grassland—to better meet animals' nutritional requirements while acting as 'natural' firebreaks. The specific grazing behaviour offers the opportunity to combine different domestic herbivores (mixed grazing) to achieve sustainable systems utilizing heterogeneous resources. Cattle, sheep, goats, and horses may have a role in the provision of different ecosystem services such as food production and biodiversity conservation. Genotype x environment interactions shape the ability of animals to cope with poor vegetation conditions, with smaller species and breeds performing better than larger animals. Goats and horses are indicated to arrest woody encroachment. Sustainable grazing systems are affordable in heathland–grassland mosaics by selecting appropriate livestock species and breeds for quality production, thus favouring rural economies and lowering fire risk.

Keywords: grazing system; herbivore; local breed; heathland; animal production; biodiversity

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1. Introduction

The Atlantic region of the Iberian Peninsula extends from the inland mountain ranges in Portugal (Castelo Branco, Coimbra, Guarda, and Viseu districts) to the north through Porto, Vila Real, Braga, and Viana do Castelo, encompassing the Spanish regions of Galicia, Asturias, and Cantabria to the Basque Country and north-western Navarra to the east. Because of the oceanic influence, it is characterized by its humid climate, with mean annual rainfalls well exceeding 1000 mm and reaching 2200 mm in some areas [1], so geobotanically the whole territory is included in the European Atlantic Province within the Eurosiberian Region [2]. The region is quite mountainous and climax vegetation usually corresponds to deciduous forests, thus sharply contrasting with the rest of peninsular area (except the Pyrenees and other high mountain ranges) where dominant climax vegetation mostly

corresponds to sclerophyllous woodlands typical of the Mediterranean Region. Apart from the relative abundance of woodlands (including natural forests and timber plantations) and semi-natural grasslands, shrublands occupy large areas throughout the Atlantic region, with heathland being the dominant vegetation type in the vast majority of acidic rangeland ecosystems. Heathlands are dominated by ericaceous shrubs and predominate on acid soils under humid conditions [3–5]. They spread across Western Europe from Portugal to Norway [6]; although, in northern areas their surface has been much reduced since the past century due to several causes such as agricultural intensification, eutrophication, overgrazing, and natural succession to woodlands after abandonment [4,5]. In contrast, heathlands are widespread in the Iberian Atlantic region probably because their history of grazing and fire management promoting their maintenance has lasted significantly longer than in northern Europe, while land use change through pasture intensification or afforestation has also been much lower in recent history [7,8].

Extensive livestock farming has been a fundamental pillar for the subsistence of rural population for centuries across Europe, especially in mountain areas, where biophysical constraints impose severe limitations for land uses other than grazing [9,10]. Heath-dominated mountain rangelands have a long history of grazing culture based on locally governed common lands [11,12]. Historical grazing cultures integrated active and targeted herding of different livestock species on different grazing routes to favour an efficient use of the available pasture resources. They also used fire at small spatial and short temporal scales to create heterogeneous heathlands where fire and grazing interacted through a series of feedback mechanisms [13]. These long-proven strategies generated mosaic landscapes of high natural value and biodiversity, the preservation of which is now claimed under several protection figures [14]. High nature value farmlands are the result of those low-input, extensive farming activities and are intended to be promoted by the European Union (EU) [15,16].

The benefiting effects of extensive grazing systems are increasingly recognized in recent years [17–19]. These systems, under proper management driven by farmers' experience and scientific knowledge, may play a crucial role in the near future under the auspices of the European Green Deal and its 'From Farm to Fork' and 'Biodiversity' strategies within the new Common Agricultural Policy (CAP 2021–2027) [20], which pursues a circular bioeconomy, healthy and sustainable food production, environmental protection, biodiversity preservation, and climate change mitigation. They offer multiple ecosystem services, including provisioning goods such as safe and quality food production, regulating processes such as carbon sequestration and fire risk reduction, supporting services, such as nutrient recycling and biodiversity conservation, and cultural benefits, such as aesthetic landscapes, ecotourism, and traditional heritage [7,21–23]. However, livestock farm numbers have been declining for decades in the less-favoured areas because of the low profit, high labour costs, marginality, and other socioeconomic reasons, so the survival of extensive grazing systems is highly compromised and marginal lands are prone to abandonment [24–26].

In the last decades, traditional husbandry relying on efficient pasture use by rustic and adapted breeds has been transformed into more specialized, simplified, and production-oriented systems, mainly in the most favourable lands [24–26]. In Atlantic Iberia, livestock systems have been mainly oriented to cattle production, dairy in coastal areas, and suckler beef in mountain areas. Despite the abundance of pastures in the region, these systems depend largely on off-farm feed and are greatly supported by the subsidies from the EU, so their profitability and sustainability may be compromised by the low net economic margins, high fluctuations in feed prices, and the decoupling of subsidies from the CAP [25,26]. The abandonment of traditional grazing cultures in large rural areas, together with the weak demographic structure, has led to imbalances in land use with drastic changes in mountain landscapes and environment, with decreases in pasture productivity and grassland areas, increases in woody vegetation, loss of biodiversity and soil impoverishment among other problems, endangering the provision of key ecosystem services [7,24,27]. The encroachment of pasturelands by dense bracken (*Pteridium aquilinum*), bramble (*Rubus* spp.), or broom

(*Genista* spp., *Cytisus* spp.) formations is common in the Atlantic region [28,29]. Such changes decrease the resilience of the rural territories and the communities living there, and increase environmental risks such as wildfires, a widespread threat throughout the northwest of the Iberian Peninsula with dire consequences for the environment and rural economies [30–33].

In this article we summarize some aspects on wildfire occurrence in Atlantic Iberia that are often glossed over, and the main burning effects on heathlands are exposed. Then, the foraging behaviour of the main domestic herbivore species is described, as well as their grazing effects on heathland dynamics and biodiversity, including its potential to reduce fuel material as a valuable ecosystem service. Analysing the economic sustainability of livestock systems, studies on animal production grazing heathland pastures and meat quality sourced from local breeds are reported. Finally, possible improvements from the point of views of grazing and land management and CAP forecasts are discussed.

2. Wildfires in the Atlantic Region of the Iberian Peninsula

In a broad context, Portugal is the most affected country by wildfires among the European Mediterranean countries [34–37]. According to the European Forest Fire Information System (EFFIS) database [37,38], the mean percentage of annually burnt area in Portugal between 1980 and 2019 is 1.25% (almost 50% of the geographic area accumulated in 40 years; although, the high recurrence of fires in the same areas should be noted), three to four times the percent values observed in Spain, Italy, and Greece (0.31%, 0.34%, and 0.32% annually burnt, respectively), while the value for France is much lower (0.04%). In the rest of the European Environment Agency member countries taken together, the percentage of annually burnt area (average from 1992 to 2019) is only 0.014%.

Looking at the Iberian Peninsula, one might think that in the Atlantic zone, with a more humid climate, the incidence of wildfires would be lower than in the much drier Mediterranean zone. It turns out that both the number of fires and the burnt area are rather greater in the northwest and Atlantic façade than in the rest of the peninsular area. According to official national data [39,40], the northern half of Portugal is where the most fires occur and the greatest areas are burnt, outstanding Guarda and Viana do Castelo with respective means of 3.1% and 2.9% of the area burned annually from 1980 to 2020, and Coimbra, Viseu, Porto, and Vila Real exceeding 2%; while in Spain the Galician provinces together with Asturias and Cantabria are the most devastated by wildfires (Figure 1). Therefore, in the Iberian Peninsula, the average climate of a region is not the main driver of wildfire incidence as is sometimes stated [41], although certain meteorological events such as droughts and warm and dry winds from the South may accentuate the risk of ignition and fire spread [42].

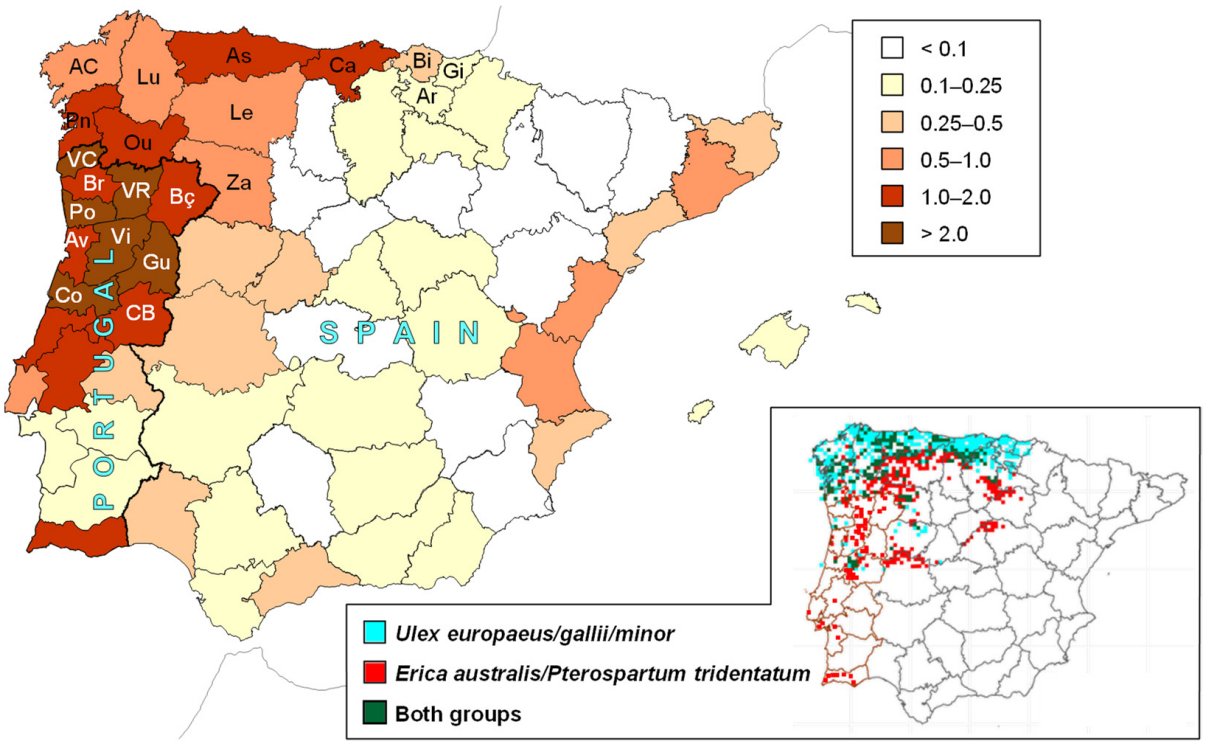

Figure 1. Annual burnt area (% of geographic area) from 1980 to 2020 by districts or provinces in mainland Portugal and Spain (including Balearic Islands). Portuguese districts included in fire data processing for Atlantic Iberia are labelled in white colour as follows: Av, Aveiro; Br, Braga; Bç, Bragança; CB, Castelo Branco; Co, Coimbra; Gu, Guarda; Po, Porto; VC, Viana do Castelo; VR, Vila Real; Vi, Viseu. Spanish provinces included are labelled in black colour as follows: AC, A Coruña; Lu, Lugo; Ou, Ourense; Pn, Pontevedra; As, Asturias; Ca, Cantabria; Ar, Araba; Bi, Biscay; Gi, Gipuzkoa; Le, León; Za, Zamora (source: [39,40]). In the lower right map, the distribution of the most pyrophilic shrub species is shown (source: [43]).

Shrublands are the most affected plant formations by wildfires; although, there are differences between Portuguese and Spanish regions. In Portugal (including the districts from Castelo Branco and Coimbra to the North), shrubland areas account for 50.4% of total burnt area from 1980 to 2020, slightly higher than woodlands with 45.4%, while the rest would be agricultural areas (data recordings from 2001 to 2020) [39]. In Spain (including the Atlantic regions mentioned above plus the provinces of León and Zamora), shrublands represent a higher percentage of total burnt area from 1980 to 2020 (65.4%), while woodlands and herbaceous pastures account for 28.9% and 5.7%, respectively [40]. Heathlands in a broad sense (especially those dominated by gorse—*Ulex* species) are the most burnt shrub formations across Atlantic Iberia [44–48]. This is related to their high accumulation of highly inflammable aboveground biomass in relatively large spatially continuous areas, favoured by their low usefulness as an economic resource (mainly as feed for livestock), so heathlands are often intentionally burned with the aim of obtaining a more nutritive pasture.

The seasonal trend of fire occurrence in Iberian Atlantic regions differs from that of Mediterranean regions, showing two main peaks for a year (late winter and mid-summer). Data from NW Spain (2006−2015) reveal that March (usually rainy) is the month when most fires occur (17% of annual totals) followed by August (15%), September (13%), and February (11%). Although August is the month when most area is burnt (almost 15,000 ha/year, 27% of total annual), most shrubland areas are burnt in March (20%) (Figure 2). Fires in Cantabria and Asturias are highly concentrated in the first quarter of the year on shrubland areas due to different reasons, such as some weather events (e.g., foehn-type dry south

winds, frequent during this time of the year), high dead matter content of shrubland biomass (more inflammable), lack of domestic herbivores in the rangelands, and the need to clear out rangeland to promote herbaceous vegetation and accessibility. Thus, in this region there is less correspondence between wildfire occurrence and seasonal climatic features such as dryness and heat that are considered as the main risk factors in other biogeographic regions such as the Mediterranean. Other factors such as human are much more important in fire incidence in Atlantic Iberia.

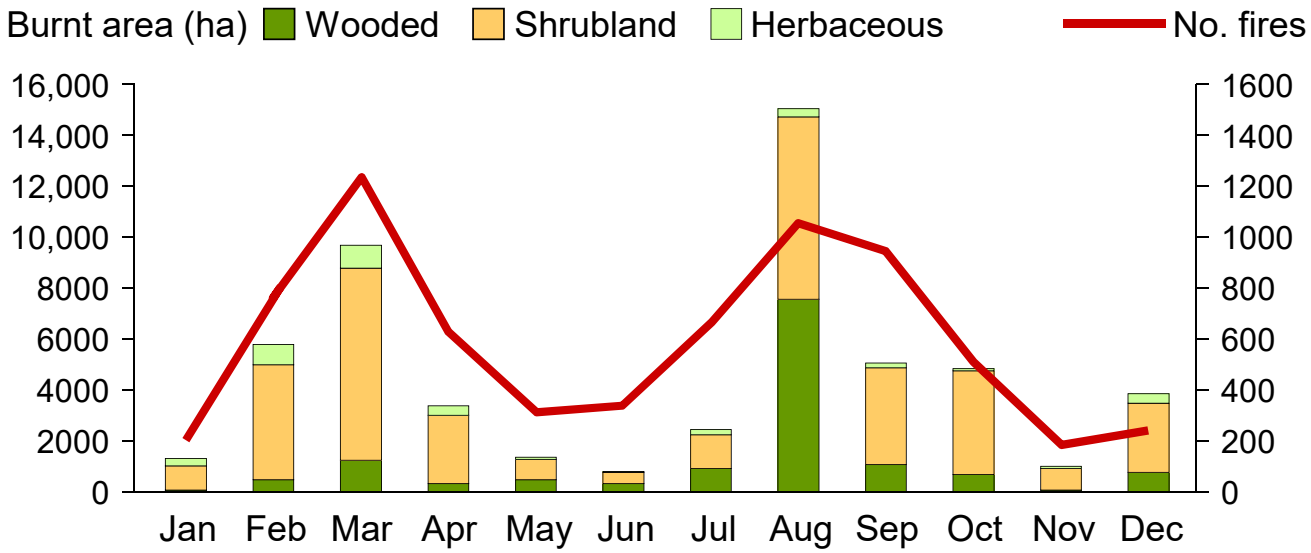

Figure 2. Seasonal trend in burnt area and number of fire occurrences (annual means from 2006 to 2015) in NW Spain (Galicia, Asturias, Cantabria, Basque Country, León, and Zamora; source: [40]).

According to data from the last decade reported (2006−2015) for NW Spain [40], 77% of fires were intentional (burning 80% of the affected areas), while those caused by negligence and accidents (mostly due to shrub burnings for pasture regeneration) accounted for 9%. Unknown causes are attributed to 7% of fires, while fires reproduced and those caused by lightning only accounted for 6% and 1%, respectively. As well, intentional and negligent fires become especially important in the northern half of Portugal [49]. As pointed above, many intentional fires are related to heathland areas. The argued reason is usually that of the farmers trying to regenerate better quality pastures; although, other causes of a psychosocial nature should not be forgotten [47,50]. However, as it can be seen in the next section, in most cases the consequences are not the most ideal: fast regrowth of woody pasture not very usable by livestock and, in the worst cases, fires affecting seriously the soil and promoting its erosion.

3. Burning Effects on Atlantic Heathlands

The post-fire recovery and dynamics of heathlands depend on multiple factors, such as fire intensity, site characteristics (soil and topography), humidity conditions, previous state and botanical composition of the canopy, the regenerative capacity of the plant species, and subsequent management. Although ashes may provide some nutrients to the soil in the short-term, most of them are readily lost by leaching or immobilization, while under very intense fires, decreases in soil organic matter content and cation exchange capacity by heat result in an overall impoverishment of soil fertility [51]. In general, post-fire recovery of heathlands occurs as an autosuccession process, i.e., the previously existing plant species are the ones that recolonize the burned surface the most [44,45,52–55]. However, there are great differences among species depending on their ability and strategy to regrow, which may be as resprouters or seeders. Some shrubs such as gorses (*Ulex* spp.) or some heathers (e.g., *Erica australis*) show a great capacity to resprout from basal buds, recovering quickly

and even becoming dominant in the recolonizing community. Other heather species (e.g., *Calluna vulgaris*) are obligate seeders and take longer to achieve pre-fire presence status in the community [54,56].

In montane heathlands of western Asturias, the gorse *Ulex gallii* has been observed to have a great post-fire recovery capacity thanks to its vegetative resprouting, but also to the stimulation of seed germination by heat [55]. This spiny woody legume becomes the dominant species in a few years by out-competing other species, accumulating great fuel amounts in monotonous canopies and creating hardly impenetrable barriers for grazing animals. Gorse stands also present lower abundance and diversity of ground-dwelling arthropods than unburned, floristically more diverse heathlands [8]. Although prescribed burning has proven to be effective to reduce fuel amount in common gorse (*Ulex europaeus*) shrublands of Galicia, fire hazard increased again after only three years after burning [57].

On shallower and stony soils or in less oceanic locations, where the presence of gorse is more restricted, other pyrophytes may lead the post-fire recolonization. In previously burnt mountain heathlands of north-western Zamora, *Pterospartum tridentatum* and *Erica australis* stood out as the dominant species (mean cover of 45% and 40%, respectively, at 10 sites), with the shrub *Halimium alyssoides* as the most important companion species (22%), while herbaceous plants accounted for 19% cover on average [58]. The floristic diversity of these heathlands, often recurrently burned, is quite poor, with a mean of 10 (range 4–15) species found in 10 m^2 per site. These woody pyrophytes have been observed to dominate the canopy in previously burnt heathlands of other regions such as Cantabrian Mountains in León [53,54]. Although herbaceous plants may have a noticeable presence in the first post-fire years; afterwards, they are replaced by the more competing shrubs [56], which generally present a very low nutritive quality and palatability for livestock. Particularly, *Pterospartum* is an aphyllous woody legume with lower protein and higher lignin contents than gorse [59]. Thus, the high resilience of heathlands to burning effects leads to very poor communities in terms of both biodiversity and feeding value for livestock, generating a dangerous vicious circle with increasingly sterile soils, or even bedrock outcropping, which prevent the establishment of productive pastures [48].

4. Grazing Behaviour and Herbivory Effects on Atlantic Heathlands

Grazing affects the structure and composition of woody pastures by means of defoliation, treading, and excreta deposition [60–62]. Apart from the established grazing regime and stocking rate, the type of herbivore (species, breed, body size, and nutritional status) and associated foraging behaviour greatly determine the effects on vegetation [61]. Domestic herbivore species (namely, cattle, sheep, goats, and horses) differ in their dietary preferences, thus affecting the grazed pastures in different ways. Cattle are considered as grazers (in the sense of grass eaters), usually rejecting woody species such as heathers and gorses, and show a less selective ability than small ruminants because of their muzzle anatomy and form of prehension [63–65]. Cattle graze preferentially on grasslands over heathlands [66,67], with open heathlands being much more utilized than close and dense heathlands [68]. Sheep also prefer grasslands compared to shrublands and show a high selective capacity to ingest the most nutritive plant items from the available pasture [63,69]. Goats are well known to use woody species in a higher degree than other domestic herbivores, even when herbaceous pastures are available, and thus they are regarded as intermediate feeders (grazer-browser) [65,66]. Particularly, goats use heathland resources more than other species [8,66] and may consume heather plants as a way of self-medication to reduce their parasitic infections by gastrointestinal nematodes [8]. Horses selectively feed on herbaceous plants such as grasses and other graminoids such as sedges (*Carex* spp.) [66,67,70], and show a high intake capacity due to their fast digestive passage rate that outweighs their lower digestive efficiency compared to ruminants [71–73], so they are strong competitors of other herbivores such as cattle or sheep for grassland use [72]. In Cantabrian heathlands, horses are able to select greater percentages of heath-grasses than cattle while rejecting heather plants [59]. The autochthonous pony-type breeds of

the Iberian Atlantic area may utilize woody pastures when grass availability becomes limited [74,75]. In heather–gorse shrublands, Galician crossbred horses preferentially feed on herbaceous plants and select greater dietary percentages of gorses than heathers [76]. In heathland–grassland mosaics, horses were found to select more gorse and less heather than cattle when herbage availability decreased [72]. Basque ponies (Pottoka breed) were observed to browse gorse more intensively at the edges of the most used grass patches [74]. The willingness of these ancestral pony-type breeds to eat gorse once grass is depleted was also observed in southern England [67].

The foraging behaviour of each animal species determines the degree of complementarity among them for the use of pasture resources. In general, goat is the species that show the lowest overlap in diet composition or plant community selection with the other domestic herbivores due to their greater willingness to feed on woody vegetation, so they complement better for the use of grassland–shrubland mosaics in mixed grazing systems [8,72]. Nevertheless, it is important to remark that, within the same species and breed, important variations in grazing behaviour and diet preferences can be found between individuals, both because of genetic differences, but also because of herd management and animal past experiences [77,78].

According to the specific grazing-browsing behaviour, marked differences between herbivore species have been observed with respect to their impacts on heathland dynamics. In previously burnt or mechanically cleared heathlands in Asturias, goat grazing achieved a greater control of woody plant regrowth, especially of gorse, resulting in greater herbaceous percentages in the canopy and lower fuel amounts than sheep grazing [55,79] (Figure 3). Comparing sheep and cattle management mixed or not with goats in mechanically cleared heathlands with adjacent grasslands, there were no marked differences between sheep and cattle in shrub encroachment; although, the mean height of gorse increased more under cattle grazing, whereas heather cover was maintained at lower levels under sheep grazing. Mixed grazing with goats resulted in lower aerial phytomass amounts, with lower gorse percentages than single sheep or cattle grazing [80] (Figure 3). The usefulness of goats as a tool to reduce woody mass accumulation and thus fire hazard has been proven in different plant communities [29,81–84].

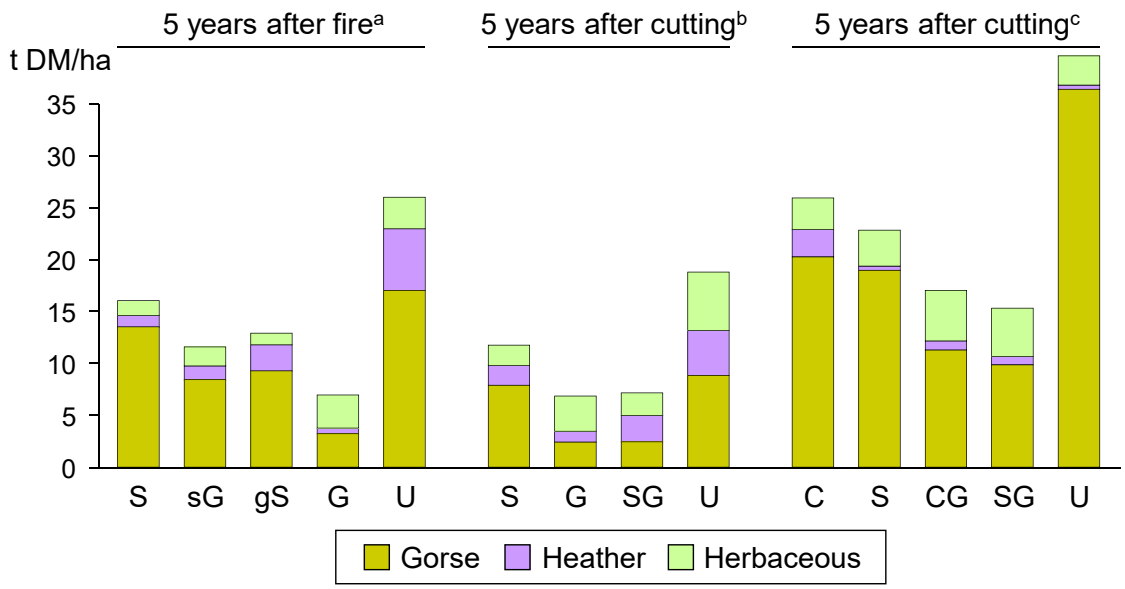

Figure 3. Woody (gorse *Ulex gallii* and heather species) and herbaceous biomass accumulation after superficial burning or mechanical clearing of heathlands subjected to different grazing managements. S: sheep; G: goat; sG: goat after initial sheep grazing; gS: sheep after initial goat grazing; SG: mixed sheep and goat; C: cattle; CG: mixed cattle and goat; U: ungrazed. a [55]; b [79]; c [80].

Despite horses' high preference for grasslands, they can be an effective shrubland management tool. Galician semi-feral ponies (Cabalo de Pura Raza Galega) have shown positive effects on plant diversity of wet heathlands dominated by *Erica mackaiana* as a consequence of increased habitat heterogeneity, thus favouring the presence of several herbaceous species typical of heath communities such as *Cirsium filipendulum*, *Gentiana pneumonanthe*, *Serratula tinctoria*, or *Scorzonera humilis* [75]. On better quality soils where common gorse is usually the dominant species, horses were much more efficient in controlling gorse regrowth after burning and clearing than cattle and sheep [85]. In Galician *Pinus radiata* stands with a common gorse-dominated understory, plant species richness and diversity increased under horse grazing, with rotational management showing greater effects than with continuous grazing because of the more intensive gorse browsing in the first case, reducing its biomass and thus forest fire risk [86]. Six years after horse grazing was stopped, although differences between grazing regimes were diluted, grazed sites still showed higher plant species richness and diversity and lower gorse dominance compared to ungrazed sites [87]. In different types of Cantabrian heathlands, horse grazing resulted in decreases in gorse cover and height and increases in heather and herbaceous cover, enhancing floristic diversity with respect to ungrazed paddocks. The reduced gorse dominance promoted the presence of heath species of conservation interest while controlling excessive fuel accumulation [76], so horses could be used as a management tool for the restoration of heathlands and their biodiversity [73,75,86].

A recent systematic review provides evidence that grazing by herbivores has the capacity to reduce combustible phytomass and, thus, fire hazard in a variety of ecosystems worldwide. The effectiveness was found to be higher at mixed grazing with both grazer and browser herbivores; although, in some cases, other management strategies, such as mechanical clearing combined with herbivory, could be needed to reduce wildfire damage [88].

5. Animal Production in Heathland Pastures

The economic sustainability of livestock farms depends primarily on animal production (meat and milk) for marketing. In extensive systems, mostly devoted to meat production, animal rearing is mostly based on pasture grazing, with limited amounts of purchased feed for wintering and offspring birth season. However, the farms relying on poor-low productive pastures such as heathlands have many difficulties to obtain sufficient income from a competitive market to be sustainable, and greatly depend on subsidies for their survival [20,25,26]. As pointed above, livestock productivity on heathland vegetation is mostly restrained by its low nutritive value that hardly meets animals' nutrient requirements [59,89–91]. The genotype × environment interaction plays a crucial role in the suitability of different animal species and breeds to different environments regarding their nutritional or abiotic constraints. In general terms, smaller or lighter species and breeds perform better under conditions of limited energy supply than heavier more demanding animals [64,89,92]. In heathland pastures, small ruminants are expected to show better productive responses than large herbivores such as cattle and equines. Studies in Asturian heather–gorse shrublands showed that positive changes in animals' body weight (BW) and condition (BC) occurred in shorter periods of only 2−3 months during spring–early summer for beef cattle and horses than for sheep and goats [59]. In heathlands grazed by cattle and horses at low stocking rates, crossbred mares showed better productive responses than cows, which were more penalized by the low nutritive value of available vegetation, especially lactating ones. With regard to the offspring, calves and foals obtained similar BW gains during the whole grazing season, although foals' gains were reduced from August onwards [59]. In heathlands of different botanical composition, horses (both mares and foals) attained more positive BW changes in those dominated by heath-grasses (mostly *Pseudarrhenatherum longifolium* and *Agrostis curtisii*) and gorse compared to those dominated by heathers thanks to their good capacity to consume gorse [76].

The genotype × environment interaction can also be noted within an animal species. Despite the higher intake capacity and productive potential of larger breeds, smaller breeds can thrive better on pastures of limited quantity (e.g., short swards) or quality (e.g., woody pastures) because of their lower absolute nutrient requirements [61,64]. Higher performances of the smaller within-species breed have been observed in cattle (Asturian Mountain vs. Asturian Valley) and sheep (Galician vs. Latxa) grazing Cantabrian summer pastures consisting of mountain grasslands (with herbage shortage from mid-summer onwards) and *Calluna vulgaris*-dominated heathlands, as well as in goats (Cashmere vs. Bermeya) grazing on montane heathlands dominated by *Erica umbellata*, *Erica cinerea*, and *Ulex gallii* [8].

In general, the studies on animal production carried out in heathlands reveal the limitations to maintain productive herds with mothers and offspring. The establishment of improved pastures by sowing grass–legume mixtures (e.g., perennial ryegrass—*Lolium perenne* and white clover—*Trifolium repens*) adjacent to heathlands aids to better meeting animals' nutritional requirements to achieve sustainable meat production systems [89,93]. In addition, these grasslands act as natural firebreaks within heathlands, reducing fire hazard, and diversify the landscape [8]. Interspersed open and close heathlands mixed with grasslands usually hold a higher arthropod diversity [8]. Therefore, the partial improvement of heathland areas may be seen as a sustainable intensification to revalue these marginal and poor lands while reducing environmental risks [94]. However, in many heathland areas, especially in protected areas, pasture improvement practices involving external calcium amendments, fertilisation, or introduction of improved forage seeds could be economically and environmentally unadvisable [5]. Further pasture improvement actions could also be performed within this grazing system where the professional herder is key element. Temporal and concentrated night camping in strategic locations can produce noticeable and beneficial effects on soil, vegetation and biodiversity [95]. Burning or slashing of individual bush plants or small thickets with null risk could also be performed routinely by the herder in his daily route, complementing the grazing and browsing of his/her herd towards the creation and maintenance of a fire-resistant landscape [96].

Mixed grazing systems, especially when small ruminants are included, may enhance the utilization efficiency of heterogeneous pasture resources such as grassland–heathland mosaics, avoiding shrub encroachment while maintaining an overall higher nutritional quality and productivity, in addition to generating greater biodiversity [65,97–99]. As commented above, different herbivore species may consume different plant items from those vegetation mixtures in a complementary way due to their distinct foraging behaviour and digestive function, thus lowering interspecific competition and increasing overall productivity [98–101]. Mixed grazing may also increase the resilience of the farms in times of economic volatility by diversifying the production and provisioning local and healthy food from territory-adapted systems with lower environmental footprint [101,102].

Comparing animal species in terms of livestock units (LU) in mixed grazing, sheep is the species that shows the best productive responses on partially improved heathlands because of the higher BW gains of lambs compared to calves, foals, and kids. Goats and horses show similar absolute gains per LU, whereas cattle present the worst productive responses due to the great BW losses of cows during summer and autumn–winter, in spite of the high BW gains of calves [72]. In addition, the needs for external or conserved fodder are much greater for cattle, increasing yearly costs. Although goat kids may present limited BW gains, the capacity of goats to utilize heathlands should not be forgotten, so, instead of competing, they may even facilitate access to more nutritive herbage for the grazer species. On the contrary, the high herbage intake capacity of horses may generate a competing scenario with other grazers for grassland resources [70,72].

Apart from the complementary or competing scenarios for resource use, mixed grazing can be beneficial in terms of soil physical attributes (e.g., compaction and water infiltration), health (microbial diversity), and nutrient contents by a more even distribution of animal excreta [97]. In addition to the different selection for grazing sites by each herbivore

species (usually driven by vegetation characteristics but also by physical features such as water points and slope), they also select different areas for resting. For example, in grassland–heathland enclosures with a certain slope, sheep have been observed to rest on the uppermost site during the night, whereas cattle and horses prefer the flattest areas to spend the night, so dung concentration is lower under mixed than under monospecific grazing, leading to a more dispersed nutrient recycling over the whole field.

On the other hand, the great wealth of local livestock breeds in the northwest of the Iberian Peninsula has to be emphasized. In the region considered in this review, 22 cattle, 10 sheep, 6 goat, and 6 horse indigenous breeds can be found, of which more than two thirds are declared endangered (Table 1). Most of these breeds are well adapted to the humid and mountainous conditions of the Atlantic region and are extensively reared in semi-natural pastures including heathlands, so they constitute an invaluable genetic resource to deliver both provisioning and non-provisioning ecosystem services on harsh environments [103]. However, there is a clear lack of studies addressing the foraging behaviour and productive potential of most of these breeds on different pasture types.

Table 1. Local livestock breeds from the Atlantic region of Iberian Peninsula and their main geographic distribution (GD; see Figure 1 for the codes of Portuguese districts and Spanish provinces).

Cattle	GD	Sheep	GD
Alistana-Sanabresa *	Za	Bordaleira Entre Douro e Minho *	Br Po VC VR (Av Vi)
Arouquesa *	Av Br Po Vi	Carranzana	Bi Ca (As Le)
Asturiana de la Montaña *	As (Ca Le)	Churra [1]	Bç Le Ou VC VR Za
Asturiana de los Valles	As (Bi Ca Gi Le Lu)	Latxa	Ar Bi Gi
Barrosã	VR (Br VC)	Mondegueira *	Gu
Betizu *	Bi Gi	Navarra	(Ar)
Cachena *	VR (Br Ou VC)	Ovella Galega	AC Lu Ou Pn (As)
Caldelá *	Ou	Sasi Ardi *	Ar Bi Gi
Frieiresa *	Bç Ou Za	Serra da Estrela	Vi (Gu)
Jarmelista *	Gu	Xalda *	As
Limiá *	Ou	**Goat**	**GD**
Marinhoa *	Av	Azpi Gorri *	Ar Bi
Maronesa *	VR (Bç Br Po Vi)	Bermeya *	As
Minhota (Galega) *	VC (Br)	Bravia	Br VR (Bç VC)
Mirandesa *	Bç	Cabra Galega *	Lu Ou
Monchina *	Bi Ca	Preta de Montesinho *	Bç (VR)
Pasiega *	Ca	Serrana	Bç Gu Vi VR
Pirenaica	Ar Bi Gi (Ca)	**Horse**	**GD**
Rubia Galega	AC Lu (Ou Pn)	Asturcón *	As
Terreña *	Ar Bi (Gi)	Cabalo de Pura Raza Galega *	AC Lu Ou Pn
Tudanca *	Ca	Euskal Herriko Mendiko Zaldia *	Ar Bi Gi
Vianesa *	Ou	Garrano *,[2]	Br Bç VC VR
		Monchino *	Ca (Bi)
		Pottoka *	Ar Bi Gi

* In danger of extinction. [1] There are at least seven related breeds or varieties in the region, some of them endangered. [2] Sometimes considered as same breed as Cabalo de Pura Raza Galega (Galician pony).

6. Meat Quality of Local Livestock Breeds from the Atlantic Region of Iberian Peninsula

In general, indigenous herd breeds have particular characteristics such as local adaptation, resistance to diseases, and high fertility [104,105]. These inherent traits of local livestock breeds make these animals ideal for breeding in extensive systems compared to commercial breeds that have not developed characteristics of adaptation to more hostile environments [106]. In this way, the use of autochthonous breeds can favour the use of heathland pastures for meat production, thus allowing the revaluation and control of these areas [23]. However, the characteristics of the meat of the animals may vary with respect to the commercial breeds generally used in the meat industry and may affect their quality in different ways [107].

In the case of cattle, it has been seen that certain local breeds provided high nutritional quality, due to their lipid profile. This is the case of breeds such as the Arouquesa veal, which is characterized by presenting intramuscular fat with high conjugated linoleic acid (CLA) contents, including the CLA isomer *cis*9, *trans*11. At the same time, it has been observed that the meat of the Arouquesa veal shows n-6/n-3 ratios within the recommended

values for the human diet [108]. Similarly, the autochthonous Mirandesa breed shows meats with favourable ratios of n-6/n-3 and interesting contents of n-3 polyunsaturated fatty acids (PUFA) and α-tocopherol [109]. Along the same lines, the veal produced from Tudanca × Charolais cross obtained better values for the lipid profile than the French Limousin breed, and also provided less tough and more tender and juicier meat, thus showing greater acceptability by tasters [110]. For its part, the Asturiana de los Valles breed showed a low intramuscular fat content when compared to other Spanish cattle breeds. Furthermore, this indigenous breed turned out to be the breed with the lowest triglyceride content. However, it presented the highest phospholipid and cholesterol amounts [111]. Finally, the Rubia Galega breed should be highlighted for being the most important autochthonous cattle breed in Spain [112]. In this case, the rearing of these animals in extensive and semi-extensive systems provides meat with a fatty acid profile in line with the nutritional recommendations of international organizations, in addition to its great palatability [113].

Regarding sheep, it has also been seen that some autochthonous breeds such as the Bordaleira Entre Douro e Minho and the Ovella Galega improved the lipid profile compared to other commercial breeds raised in intensive systems. Specifically, a recent investigation showed that the meat of Bordaleira and Galega lambs had high amounts of n-3 PUFAs and favourable values of n-6/n-3 ratio, as well as a high content of α-tocopherol when it was compared with lambs of the commercial breed INRA 401 [107]. Furthermore, in the case of the quality of sheep meat, especially lamb meat, it is worth highlighting the importance of volatile compounds, since these substances play a crucial role in consumer acceptance [114]. In this sense, it has been found that breeds such as Navarra provided lambs with a positive meat sensory odour and flavour quality after aging [115].

As for the quality of goat meat of the native breeds, few studies have been carried out on it to date. However, investigations on goats of the Serrana and Preta de Montesinho breed can be highlighted, which have shown that these animals have tender meats, between dry and medium juicy, with easy chewing and with a fairly intense smell and flavour, but without high persistence [116]. Moreover, it has been seen that the Bravia and Serrana breeds contained 60% of the desired fatty acids in their intramuscular fat composition, at the same time that Bravia kids had dark and red meats [117].

Similar to what happens with goat breeds, the quality of the native horse breeds has been little studied to date. However, it is known that horse meat is characterized by having a high nutritional value since the foal meat has high value proteins, iron, B type vitamins, as well as a low amount of fat and cholesterol and a favourable dietary fatty acid profile [106]. Along these lines, it has been found that the native breed Cabalo de Pura Raza Galega is more suitable from a dietary point of view than other meats such as veal or beef, since it has a more favourable relationship between saturated and unsaturated fatty acids [118].

As has been described throughout this section, autochthonous breeds have intrinsic characteristics that can affect compositional, nutritional, and sensory values, which in turn determine consumer acceptance [113,119]. However, the diet and the livestock production system are two factors that also greatly influence these quality parameters [113,118,120]. In this way, the use of heathlands in the grazing of animals destined to produce meat could have some impact on the characteristics of the meat, regardless of the breed and the animal species. Despite this, research that focuses on the influence of heathland feeding on meat quality is non-existent to date, so starting studies in this field is a challenge to achieve. Additionally, the use of this undervalued pastureland with indigenous breeds offers consumers an image of sustainable meat, which agrees with current thinking, since the European population has developed a preference for biological practices and organic production methods [121], once again showing the suitability of initiating investigations in this line.

7. Final Reflections on the Future Sustainability of Livestock Production Systems in Fire-Prone Heathlands

The mighty limitations of heathland-dominated areas to support sustainable livestock production systems are causing imbalances in rangeland use that are leading to several environmental risks, of which wildfires appear the most severe, though not the only one. The abandonment of traditional grazing systems towards free-ranging herds, mainly of cattle and horses, has led to undesirable changes such as scrub invasion and decreased pasture productivity, restraining their use by livestock. The recovery of these sites, usually in mosaic with the heathland, is key to attain sustainable grazing systems, as it would allow meeting animal daily requirements and also would facilitate the consumption of heathland herbaceous and woody vegetation near the patches of better pasture [68,74]. The use of small ruminants guided by herders on well planned routes [122] seems almost inescapable, as low-quality heathland will almost always be the main component of the landscape. The added cost of herding should be assumed by the increase in the pool of ecosystem services it provides, both provisioning (increase in animal productivity) and non-provisioning (e.g., fire prevention, pastoral culture maintenance, etc.). Examples of quantification and public payment of non-provisioning ecosystem services produced by herders and their herds in other mountain areas of Spain [123,124] could as well be implemented in our conditions. Partial improvement of heathlands has been successful in some mountain areas to maintain productive mixed herds, including sheep and goats, in a sustainable way [72]. The multifunctionality of interspersed herbaceous pastures within heathlands as cheap firebreaks and landscape diversifier provides more ecosystem services than those of merely provisioning. Nevertheless, the suitability of a particular area to sustain this type of land intensification should first be carefully assessed.

In addition to the natural biotic and abiotic limiting factors, socio-economic factors derived from the CAP greatly influence the farmers' decisions on land use and animal management, and many times the proposed guidelines are not the most appropriate in terms of a sustainable use of the territory [20,125]. Nowadays, CAP payments are crucial to the survival of the extensive livestock farming systems using the rangelands of northern Spain and Portugal. Up to now, most of the annual CAP payments received by livestock farmers depend upon the forage land they use. Heathlands and other types of woody vegetation have been questioned in the last years as being eligible pasture. In general, the determination of pasture eligibility in shrub formations has been biased towards the grazing behaviour of cattle and horses, not considering that, in the case of small ruminants (especially goats), browsing high thicket stands, which are currently considered totally ineligible as pasture, is more a norm than an exception. In order to improve the relationship between CAP payments and the provision of ecosystem services promoted by farmers in these rangelands, there is a need to address their functioning at the whole landscape level and not merely at each of the land parcels in which is administratively divided. These payments should be received according to well-defined targets and grazing management plans that improve or maintain the provision of ecosystem services at the landscape level. These plans should consider (i) the promotion of small ruminant grazing as the most efficient in these ecosystems while at the same time highly threatened by wild predators; (ii) the adoption of targeted grazing through the promotion of a renewed profession of skilled herders aided by valuable innovations, such as GPS collars and other sensors attached to animals, or remote sensing devices capable of predicting the spatiotemporal distribution of forage productivity; and (iii) boost the local governance of the rangelands and the engagement of farmers and other neighbours in their correct functioning.

Forestry per se has not been dealt with in this work; although, it is also part of the fire problem due to the great amounts of highly combustible phytomass in the understory in poorly managed stands [31,33]. The multifunctionality of forest lands should be encouraged to maintain clearer understory vegetation. Silvopastoral systems are affordable in many forest types, in which grazing animals can remove much of the standing fuel while enhancing biodiversity and soil fertility [88,126,127].

The choice of grazing systems to implement in heathland areas should consider both the productive capacity of the different animal species and breeds and their ability to efficiently use the available vegetation, so that productive pastures are maintained while controlling the expansion of woody pastures and associated fire hazard. Future policies should encourage those extensive systems, especially mixed grazing systems with well adapted local breeds, to maintain sustainable livestock farms in both economic and environmental terms, so the delivery of multiple ecosystem services such as provision of quality food, fire risk reduction, and biodiversity conservation is ensured or even enhanced. From the productive point of view, meat quality must be appreciated appropriately reflecting its safety, health, and sensory attributes, while not forgetting other highly valued products such as traditional cheeses. In addition to the product intrinsic quality, the production system has to be clearly identified and differentiated, so consumers can value the beneficial effects of extensive systems in its fair measure. Product quality certifications such as PDO (protected designation of origin), PGI (protected geographical indication), or 'Mountain product' should be promoted for that purpose. The promotion of these products must be facilitated and subsidized by government bodies. As well, the conservation of endangered indigenous breeds should be encouraged because of their specific food characteristics regarding consumer preferences, which may not be found in commercial breeds, and their environmental role. However, the monetary valorisation of non-provisioning ecosystem services is very difficult due to multiple focusing criteria according to the different objectives and social demands [128,129].

On the other hand, some productive strategies could be adopted to increase the revenues of extensive farms. For example, many regional farms sell their animals (weaned offspring) to enterprises of other regions for fattening, thus losing potential market value [106]. Although pasture-based fattening in the region of origin could be an option, it would mostly rely on commercial feeds during finishing to ensure product acceptance by consumers, meaning increased costs. Producing other meat types, such as steer or ox meat, could be an alternative given the high market demand for this type of product, but farmers need to ensure its commercialization to safeguard their investment. Local or regional commercial circuits should be encouraged to trade extensively produced meat at fair sales prices. A mutual support between local farmers, public administration and trading circuits is essential to achieve sustainable animal production systems in less-favoured mountain areas. In addition, governments must promote and activate strategies to reduce existing inequalities between rural and urban areas. Modern technological means must be provided to rural population (e.g., access to broadband internet) and, specifically, to farmers (funding for the acquisition of IoT sensors and access to GIS platforms for remote pasture monitoring) to improve their living, social, and working conditions, whilst offering a fair and stable income, so that they can maintain their economic activity for global social benefit.

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