The role of grasslands in the less favoured areas of Mediterranean Europe

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Abstract

Mediterranean extensive grassland-based systems were in the past and are currently subjected to the contrasting threats of intensification and abandonment, especially in less favoured areas. Despite the strong socio-economic and environmental differences between and within the Mediterranean regions, they share common issues on grasslands. One of the main issues is to increase the sustainability of grasslands and the grassland-based systems. In this paper, we discuss some key factors that can strengthen the resilience and adaptability of grasslands and which could be considered also as mitigation strategies for climate change. Additionally, to enhance the results of agronomic practices, both public perception and management schemes about less favoured areas should urgently be reoriented in order to increase the attractiveness of extensive systems against intensive agriculture. For this reason, there is a rising demand for scientific knowledge and new holistic approaches aimed at (1) supporting the optimization of the economic performance of extensive livestock systems by increasing the added value of products, and (2) encouraging policies for the development of sustainable farming systems, where farmers are also rewarded for their supply of ecosystem services.

Keywords: extensive farming systems, marginal areas, ecosystem services, product quality

Introduction

In the European Union, less favoured areas (LFAs) is a definition applied to mountainous or hilly areas or areas with natural handicaps for cropping (lack of water, harsh climate, short cropping season), or that are remote, with difficulties in rural mobility or that are at risk due to depopulation. LFAs are widespread in the Mediterranean region (EEA, 2004). Despite their biophysical and structural limitations, LFAs have greatly contributed to sustain the rural economy in the northern Mediterranean basin. In these areas low-intensity and site-specific agricultural practices, mainly based on grassland resources, were developed to limit the risks associated with inter- and intra-annual climatic fluctuations and ensure more regular production (Caballero *et al.*, 2009; Jouven *et al.*, 2010; Hadjigeorgiou, 2011). Moreover, an integrated land use pattern was developed, which promoted multifunctionality at field, farm and landscape levels (Henkin *et al.*, 2011; Sternberg *et al.*, 2015). As a consequence, the agrarian landscape in the European Mediterranean regions appears as a complex mosaic of feed resources, animal species and local breeds as an effect of the local socio-cultural traditions. The practices carried out in these areas are often considered environment-friendly and landscape-preserving, and farmlands evaluated are of High Nature Value (Opperman *et al.*, 2012). In fact, Mediterranean grassland-based systems are usually extensive, with a low use of pesticides, fertilizers, concentrates and irrigation, where small ruminants predominate due to their high efficiency in the use of available feed resources (Cosentino *et al.*, 2014; Porqueddu, 2008). These farming systems have been shown to be resilient to frequent but moderate disturbance factors (i.e. deforestation, periodic fires and grazing) by developing strategies to maximize production of multiple goods and ecosystem services over several millennia (Plieninger *et al.*, 2010; Zapata and Robledano, 2014). This background gives room for optimism on the perspective that new grassland-based farming systems could be developed also in response to changing climate scenarios. Unfortunately, such systems are currently subjected to the contrasting threats of intensification and abandonment (Moreira *et al.*, 2011; Kyriazopoulos *et al.*, 2013). Moreover, as pointed out by Porqueddu *et al.* (2016), the decreasing public sector support for grassland research requires a greater level of international scientific cooperation among the few institutions operating in the different Mediterranean-climate areas of the World.

The aim of this paper is to describe the current state and role of grassland-based extensive farming systems in the LFAs of the Euro-Mediterranean regions. In the first part, an overview of the evolution of the area of grasslands and of the related farming systems of the main Mediterranean countries will be given. In the second part, the productive aspects and the main key agronomic tools for the rehabilitation and adaptation to climate change will be listed, with the awareness that research outputs in this field are just a part of an holistic approach to grassland evaluation, involving also market and policy initiatives aimed at fully recognizing the environmental and cultural role of grassland-based systems.

Grassland areas and LFAs in the main Euro-Mediterranean countries

LFAs cover 25% of the European surface, and permanent grasslands around 61 million hectares across the EU-28 (Eurostat, 2012), representing 16% of the area of EU ecosystems (MAES, 2016), while accounting for 35% of the total EU Utilised Agricultural Area (UAA). In the main Euro-Mediterranean countries (Greece, Italy, Portugal and Spain), there are over 15.2 million ha of permanent grasslands in total. According to EUROSTAT (2012), these four countries show a considerably lower proportion of natural or agriculturally improved grasslands compared to the states of northern and central Europe (Table 1). Nonetheless, grasslands constitute a large share of the UAA in the South European countries.

Mediterranean grasslands, by the definition of Peeters *et al.*(2014), are represented by mesic and sparsely wooded grasslands (EUNIS habitat type), but traditionally, wooded grasslands with up to 10-40% tree and shrub cover are used to support livestock production in these regions (Suttie *et al.*, 2005). In fact, within the European context, Southern countries are particularly rich in forest and wooded land and Mediterranean garrigue or other shrubby vegetation cover (Huyghe *et al.*, 2014; INFC, 2015). This is the reason why the available data referring to 'pastures' (e.g. FAOSTAT data) are sensibly higher than the statistics for grassland area in EUROSTAT reports. The importance and economic role as feed resource of wooded pastures and shrublands increase in LFAs. Some farming systems, diffused in these countries, make large use of another feed resource, the temporary grasslands, especially in Italy.

Portugal and Spain

In the Iberian Peninsula, the most abundant pasture types in dry mountain areas are oak and pine forests, alpine pastures, permanent meadows and xerotrophic grasslands. In the inland regions shrublands and natural pastures are predominant, with steppic vegetation in the arid areas (Caballero *et al.*, 2009). Finally, in the *dehesas* and *montados* of the SW region, open forests of evergreen holm oak are the dominant landscape, providing grass, browse and acorns for cattle, sheep and ranging pigs. The relative proportion of the different pasture types has changed in the recent past. In Portugal, permanent grasslands increased by +30% between 2000 and 2013, as a consequence of the +50% rise of the rough grazing area (pastures grazed at low stocking rates), while the *montado* has an estimated annual regression rate of -0.14% per

Table 1. Land covered by different pasture types in the main Euro-Mediterranean countries (EUROSTAT, 2012; INFC, 2015).

	Portugal	Spain	Italy	Greece	France[1]
Natural or agricultural improved grassland (% total area)	16	16	17	14	18
Grasslands (% utilised agricultural area)	50	34	27	43	68
Forest and wooded land (% total area)	37	30	33	30	40
Mediterranean garrigue or other shrubby vegetation (% total area)	18	17	7	26	17

[1] Only Mediterranean regions: Provence-Alpes-Côte d'Azur, Languedoc-Roussillon and Corsica.

year (Godinho *et al.*, 2016). On the opposite, in Spain grasslands have decreased by close to -15% in the 2000s, namely because of the increase in shrub and forest areas. These have been caused by the changes in extensive livestock censuses, but also because of the different management patterns applied to the grazed lands. A similar trend has been observed in dry mountain areas, where the intensification of management in sheep farms was negatively related to the use of natural grazing resources (Riedel *et al.*, 2007), and lack of succession compromised the continuity of the most extensive farms. But the consequences of these land use changes can be diverse and sometimes positive. For example, in the *dehesa*, a certain degree of shrub encroachment by given species has proven to facilitate tree regeneration and maintain or even enhance pasture, browse and acorn productivity (López-Díaz *et al.*, 2015).

Italy

LFAs are mainly lands with natural handicaps, where the severity of slopes is the main determinant of the vegetation types. Seeding is carried out on slopes up to 25-30%. The steeper slopes (gradient up to 35-40%) are covered by woods and permanent grasslands and the more severe slopes (gradient >40%) are overgrown by forests and pastures. The pasture types than can be found are very variable and characterized by several tree associations. In central Italy, Mediterranean shrubland associated with evergreen schlerophyll trees and shrubs (*Quercus ilex*, *Quercus suber*, *Quercus coccifera*) can be found along the Thyrrenian coast; forests of deciduous trees (e.g. *Castanea sativa*) prevail in mid hills and forests of *Fagus sylvatica* in mid mountains. Finally, natural meadows are associated with various types of vegetative association (*Brachipodietum*, *Brometum*, *Arrhenatheretum*, *Festucetum*, *Lolietocynosuretum*) in high mountains. In Southern Italy, grasslands are associated to thermoxerophytic shrubs along the coasts, together with forest and evergreen sclerophylls. Forests of holm oak are common in mid mountains, where they form mixed woods with the deciduous species *Quercus pubescens* at higher altitudes. Permanent grasslands are found mainly in the Apennine zone above 500 m a.s.l., while more recent agriculturally improved pastures are present in the lower zones. Permanent grasslands underwent a gradual reduction from 1990 to 2000, when more than 340,000 ha were lost, while from 2000 to 2013 their area remained stable (EUROSTAT). The largest decrease involved pastures and meadows. Currently, permanent grasslands and pastures are widely diffused in the main islands (Sardinia and Sicily, 40.7% of their UAA), then in the regions of North West (32.5%), North East (24%), Southern Italy (20.6% of their UAA) and Central Italy (18.5% of UAA) (ISTAT, 2016).

Greece

About 50% of the country's grazing lands are found in mountainous areas (>600 m a.s.l.) and a further 30% in hilly areas (300>x>600 m a.s.l.) and the majority are covered by woody vegetation. The CORINE 2000 data describe the land covered at 10% by grassland and phrygana, 17.7% by sclerophyllus vegetation, 9.4% by transitional shrublands, while a further 18% is covered by forest. Grazing lands are predominantly (75%) State- or community-owned lands which are used as Common land within each municipality (Hadjigeorgiou *et al.*, 2002). Common land in Greece accounts for 49% of the UAA and represents mostly rough grazing areas used to pasture cattle, sheep and goats. However, a much larger area is grazed to a varying degree, which includes a large part of forests, permanent crop (e.g. olive groves) and annual crop fields (e.g. cereal stubbles etc.) thus increasing the total area affected by pastoralism to about 65% of the whole country. Therefore, landscapes and biodiversity of the Greek land, which have been shaped through the ages by livestock husbandry (Hadjigeorgiou, 2011), are still maintained by pastoral activity. The grassland habitat type with the highest share of plant associations is *Thero-Brachypodietea*, which includes the annual plant communities (Mucina, 1997). Furthermore, 17 grassland habitat types covering 137 plant associations have been recorded (Dafis *et al.*, 2001). The most common grassland phytosociological classes are *Junceteatrifidi, Festuco-Brometea* and the mesophile and wet heaths of the class *Molinio-Arrhenatheretea* (Fotiadis *et al.*, 2006). However, the plant communities closely associated with sheep and goat grazing are those of the high calcareous mountains dominated by dwarf shrubs

(*Daphno-Festucetea*), usually with many endemic species (Alados *et al.*, 2004; Bergmeier, 2002) and those of the xerothermic lowland areas with dwarf, dry-tolerant shrubs (phrygana of *Cisto-Micromerietea*), where the plant diversity is very high (almost 100-120 species per 200 m^2) (Bergmeier, 2002; Phitos *et al.*, 1995; Tan and Iatrou, 2001).

On the Greek mountains woody vegetation consists of a variety of tree (*Quercus frainetto, Ostrya carpinifolia, Tilia tomentosa, C. sativa, F. sylvatica, Carpinus orientalis* and coniferous forests of *Pinus nigra, Abies* spp., etc) and shrub species (*Juniperus foetidissima, Vaccinium myrtillus, Rubus* sp. and *Rosa* sp.). Major vegetation types associated with pastoral activity are the phryganic vegetation (*Phlomis fruticosa, Sarcopoterium spinosum, Coridothymus capitatus, Cistus* spp.) and the garrigues (*Q. coccifera*, *Pistacia lentiscus*, *Arbutus unedo*, *Juniperus phoenicea*) (Caballero *et al.*, 2009).

Mediterranean France

About 72% of the surface of Mediterranean France (comprising Provence-Alpes-Côte d'Azur, Languedoc-Roussillon and Corsica) is considered as mountainous or disadvantaged areas (98% only in Corsica). In these three regions, the percentage of forage crops and permanent grassland on the UAA is on average 68%, with a very high percentage in Corsica (more than 90%). Non-productive permanent grasslands characterize large hilly and mountain areas of all three regions. Woodlands represent a very important trait of the mountain landscape covering around 40% of the total surface, protecting the soil against erosion and preserving biodiversity. These regions benefit from agri-environmental measures dedicated to pastoral systems, and grazing animals are directly involved in the overall system of forest fire prevention and utilized for fuel biomass-reduction purposes within firebreak-management plans (Pastomed, 2007).

Livestock population and farming systems in the main Euro-Mediterranean countries

The livestock in the four main Mediterranean countries of Europe accounts for around 96.7 million heads, corresponding to 29% of the total amount for EU-28 (EUROSTAT, 2016). They host 17% of the cattle, 28% of the pigs and up to 39 and 67% of the EU-28 sheep and goat census, respectively (Table 2). In particular, sheep and goats represent most of the grazing livestock units in Greece (73%) and Spain (32%). Moreover, and unlike most European countries, in Spain and Portugal there are more suckler cows used for meat production than there are dairy cows.

Portugal and Spain

In Portugal ruminants are predominant (59% of the census, in terms of livestock units, LSU), while in Spain pigs and poultry represent a larger share (57%) (EUROSTAT, 2016). This is the result of intense changes in the number of farms and their orientation in the previous decade (2000-2010) in both countries. In Portugal the number of livestock holdings decreased by -36% and LSU by 13%, with the

Table 2. Livestock census by species in the main Euro-Mediterranean countries (EUROSTAT, 2016), thousand heads (% of EU-28 census). Data are referred to 2015.

	Cattle		Pigs		Sheep		Goats	
EU-28	89,152		148,724		85,524		12,502	
Portugal	1,606	(2%)	2,247	(2%)	2,043	(2%)	373	(3%)
Spain	6,183	(7%)	28,367	(19%)	16,523	(19%)	3,010	(24%)
Italy	6,156	(7%)	8,683	(6%)	7,149	(8%)	962	(8%)
Greece	582	(1%)	877	(1%)	8,852	(10%)	4,017	(32%)
France[1]	343	(0.4%)	587	(0.6%)	1,190	(1.4%)	104	(0.8%)

[1] Only Mediterranean regions: Provence-Alpes-Côte d'Azur, Languedoc-Roussillon and Corsica.

sheep census decreasing by -24%. In Spain, farm numbers decreased by -41% (especially the smallest ones, while mega-farms larger than 500 LSU increased by +32%), but the total LSU only changed by -1%. This masks heterogeneous patterns across animal species, with increments of poultry and pigs (+11 and +7%, respectively) and reductions in other species (-7% in cattle, -20% in sheep and goats). Pig numbers have increased both in intensive and extensive farms, and it is remarkable that the number of extensively managed Iberian sows have more than doubled in the recent past (+146% from 1995 to 2015) (MAPAMA, 2015). The attractiveness of the high prices paid for Iberian ham has sometimes altered the equilibrium between the supply and demand, with an effect on market prices. In the case of ruminants, trends have been very different considering the orientation of livestock production. Cattle censuses have decreased significantly since 1995 in the dairy sector (-37%), mostly because of the reduced competitiveness of small holdings, but the number of suckler cows in extensive farms has increased (+17%). On the opposite, the number of sheep in extensive meat-oriented production systems has decreased sharply (-38%), but the higher added value of dairy products has buffered the impact for milk-oriented sheep farms (-4%) (MAPAMA, 2015). In Spain, all the extensive Iberian pig farms, and most of the sheep (93%) and suckler cattle farms (74%) are concentrated in Mediterranean regions. In these areas ruminant production is based on extensive farming systems where beef cows, sheep and their lactating offspring graze throughout most of the year on the aforementioned pastures, but after weaning, lambs and calves are frequently fattened off-pasture, on high-concentrate diets. Transhumance is still utilized to overcome the seasonality of forage production by moving herds short or long distances between summer (highlands or Northern areas) and winter pastures (lowlands, Southerly latitudes). Another common practice is to associate ruminant farms to cereal crops, enabling them to increase their self-sufficiency by combining the use of natural pastures with stubble and fallow in croplands (Olaizola *et al.*, 2015). In the *dehesas* and *montados*, systems commonly include a mixture of beef cattle, sheep and pigs raised on these sylvopastoral areas for extensive meat production (Gaspar *et al*, 2007). Extensive pig production using the autochthonous Iberian breed is unique to this ecosystem, where animals use herbaceous sources during the spring, with supplements in the summer and are kept on pasture and acorns (*montanera*) in the autumn and early winter. Depending on birth season and forage availability, pigs can be finished indoors on concentrates or ranging on the *montanera,* resulting in a particular meat quality (Timón *et al.*, 2002) that confers a high added value to this product.

Italy

Updated data referred to 2015 on consistencies of the main grazing livestock animal categories are reported in Table 2. In relative terms, cattle heads recorded a decrease of about 3.6% in the last ten years, pigs a reduction of 5.6%, while the numbers of sheep and goats have remained stable (+0.02 and +0.05%, respectively). More than 60% of animal heads are raised in the northern regions with intensive systems. Nearly 60% of national livestock holdings are located in the central-south regions and on the main islands (EUROSTAT, 2012), where the larger part of the labour force in national agriculture is working. In the last ten years, the number of livestock holdings has decreased drastically (-65%), but at a higher rate than livestock heads: -0.6% at national level, with higher peaks in Central Italy (e.g. -25% in Tuscany). The smallest size-class farms in the mountainous regions in central Italy were the most affected by reduction (e.g. -83% in Marche region) while the larger size holdings (>500 LSU) showed an increase in number (+9%), indicating a deep restructuring of the livestock system in Italy (EUROSTAT, 2012). Due to the uneven distribution of livestock among species, cow milk is the main animal production, except for Tuscany and Sardinia, where sheep milk is produced. Sardinia, in particular, is the Italian leader in sheep rearing: 43.8% of total heads of the country are found in the island that is the centre of the Pecorino Romano PDO cheese industry. In LFAs of Central and Southern Italy and Isles, the traditional farming system is based on both temporary and permanent grasslands and, occasionally, on woody pastures that are grazed by locally-adapted breeds during summer, sometimes in mixed farms (cattle and sheep). Animals are then fattened on farm in the richer plains. Pastures are also used in the higher altitudes of the Apennines in the summer period by sheep and cows. Transhumance is currently practised in rare cases. Goat farms are mainly located in the most difficult areas. The forage systems are quite variable, depending on the farming systems. On the coastal plains and in the dry low hills where mixed crop-livestock systems are present, the base of the feeding systems is a combination of annual forages and cereal stubbles. In hills where there are possibilities for mechanization, feeding systems based on permanent grasslands and the use of hay storage and pastures are diffused. The agro-pastoral systems, widespread in interior hilly areas with little mechanization, are based on diversified resources, and semi-natural grasslands and improved pastures coexist in the better areas. Finally, silvopastoral systems are based on woody pastures, but grazing-animal breeding is associated with other agricultural activities to improve the income of farmers (e.g. cork production in Sardinia).

Greece

The grazing livestock population is composed by cattle, sheep and goats which comprise by far the largest part of the raised herds, while other herbivorous animals (horses, asses, mules and pigs) are minor (3% of LSU) additional potential grazers. Livestock production represents about 27% of the total Greek Agricultural production value. Within this value, sheep and goat products contribute 60%, of which milk is the largest part (38 and 22% for milk and meat, respectively) (HMA, 2011). Similarly to other Mediterranean countries, these animal figures have undergone substantial changes over the last two decades (1994-2014). Most notable changes were registered for the numbers of goats (-26%) and cattle (+12%) while the numbers of sheep were relatively stable (+4%). However, a strong shift was experienced in the direction of production within each species, since dairy cattle were reduced and suckler cows increased, while sheep and goats shifted towards specialization of milk production and the rejection of the old mixed production system. Moreover, the respective farms were reduced sharply (about -30% for cattle, -45% for sheep and -70% for goats), due to the intense evolution towards specialization and reorganization of this sector (Hadjigeorgiou, 2011, 2014). This trend involved mostly small units, whereas the medium and large sized units became larger and more specialized, and based on production intensification. Moreover, there was a movement from higher altitudes (mountain and semi-mountain areas) to the lowlands and closer to the population centres (Dover *et al.*, 2011). Therefore the decrease in farms coupled with an increase in headage suggest that holdings are intensifying livestock production by feeding in barns rather than by shepherding or transhumance, especially as much of the income of a sheep and goat farm derives from milk production requiring high hygiene standards and easy access to dairies (Galanopoulos *et al.*, 2011). These changes have tremendous effects on the status of rural societies and on the use of grasslands. On the other hand, feeding systems changed towards higher use of concentrate feeds while the forage systems that sustain grazing animal production in Greece are very limited. Forages are cultivated in some 400,000 ha, of which warm-season crops like lucerne (*Medicago sativa* L.) or forage maize (*Zea mays* L.) hold a large share (30 and 14% of the area, respectively) being cultivated mostly using irrigation, while the cool-season forage crop are barley and oats for hay (48%) accompanied by vetch for hay (6%). All other forage plants are cultivated very marginally.

Mediterranean France

In the three Mediterranean regions of France, grazing livestock comprise cattle, sheep and goats, with some peculiarities for each region. In the sheep sector, Languedoc- Roussillon (LR) has two distinct chains, sheep milk and meat. The first one is an intensive production system with highly priced milk sold to the industry for the manufacture of DOC Roquefort and other products. There is a reduction of sheep meat livestock, but with valorization of local breeds through collective certifications. Provence-Alpes-Côte d'Azur (PACA) is specialized in sheep meat production with three emblematic farming types: one is outdoors (plein air), with the use of the steppe areas of Crau and large transhumance, one in the foothills and arid plateaux (sometimes in combination with grain or hay productions) and a third on mountains, with possible dual activities. In Corsica, the dairy sheep sector is strongly related to the production of the

PDO cheese Brocciu. Goats are relevant for the livestock sector in LR and Corsica, with systems ranging from pastoral to almost intensive. For the cattle sector, LR and PACA still maintain interesting extensive dairy systems in pastoral lands (*estives* and *alpage*), even if this is within a general trend of reduction in the number of heads.

Primary production of grasslands in Mediterranean environments

A severe limitation for grassland productivity in the LFAs of the Mediterranean basin is represented by physical constraints, which complicate the mechanization of soil tillage, and climate characteristics, namely summer drought coupled with high solar radiation levels, cool winter temperatures during the growing season, and highly erratic and variable rainfall. For these reasons, annual species prevail in semi-natural Mediterranean grasslands. Their growing season ranges from 4 to 10 months, depending on rainfall amount and timing and plant tolerance to water deficit (300-1000 mm). It is characterized by two growing peaks, in spring and autumn. Dry matter accumulation ranges between 110 kg ha^{-1} day^{-1} in the most favourable season (spring) and 20-40 kg ha^{-1} day^{-1} in autumn (Snaydon, 1981; Caredda *et al.*, 1992). Annual and inter-annual forage productions under rainfed conditions are usually extremely variable, but generally limited, and depend on the grassland management and soil fertility. Typically, average dry matter yields range from 0.5-1.0 t ha^{-1} $year^{-1}$ in semi-natural grasslands, which prevail in marginal soils, to 6.0-7.0 t ha^{-1} $year^{-1}$ in agriculturally improved grasslands (Huyghe *et al.*, 2014). In grasslands subjected to shrub encroachment, herbage production and its nutritional value both decline with the increasing of shrub cover (Zarovali *et al.*, 2007). In the latter case, an appropriate agronomic or grazing management aimed at controlling shrubs should be introduced to promote grassland renovation and conservation (Bagella and Caria, 2011). In semi-natural grasslands, forage usually has a low quality, often worsened by a relative high rate of unpalatable species. A better forage quality can be attained by applying P-fertilizers once a year to boost production of annual pasture legumes, but when their natural seed bank is not sufficient, the re-sowing with annual self-reseeding pasture legumes is appropriate (Porqueddu and Gonzales, 2006). The most used mixtures include 3-4 species and are based on subterranean clovers (*Trifolium subterraneum* L. *sensu lato*) and annual medics (*Medicago* species). More recently, complex seed mixtures (10-20 components) have been utilized with contrasting results (Porqueddu *et al.*, 2010).

To complement the insufficient pasture production in Mediterranean regions, annual temporary grasslands are widely exploited because of their high growth rates in winter and flexible use. Traditionally, mixtures of annual forage legumes and winter cereals (oats, barley and triticale) or grasses (especially Italian ryegrass, *Lolium multiflorum* Lam. ssp. *italicum* and ssp. *westerwoldicum*) are used for short-term forage crops on arable lands. The most used legume species are common vetch (*Vicia sativa* L.), woolly pod vetch (*Vicia villosa* ssp. *dasycarpa* (Ten). Cav.), Persian clover (*Trifolium resupinatum* L.), crimson clover (*Trifolium incarnatum* L.) and berseem clover (*Trifolium alexandrinum* L.). These temporary grasslands are exclusively cut for hay production or mowed after the winter grazing (one or more grazings per season). Often farmers harvest forage with a delay which has negative consequences on quality. Recently, farmers have introduced some mixtures based on annual self-reseeding pasture legume and winter cereal to extend the duration of temporary grasslands to two or three years. Among perennials, lucerne represents the primary temporary grassland species for neutral and alkaline soils. Very frequently, the seed of local ecotypes is utilized in pure stands as green forage, hay or dehydrated forage (3-4 cuts between June and October). In the LFAs, lucerne stands typically persist for 3-4 years under rainfed conditions or occasional irrigations, before a rotational crop is grown. Despite their widespread natural distribution in hilly areas, the perennial legumes red clover (*Trifolium pratense* L.) and birdsfoot trefoil (*Lotus corniculatus* L.), which are adapted to moderately acidic soils, have been little sown. The same is true for sulla (*Sulla coronaria* (L.) Medik.) and sainfoin (*Onobrychis* spp.), although there is renewed interest in these perennial legumes (Re *et al.*, 2014). A few varieties of perennial grasses, particularly cocksfoot (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.) and bulbous canary grass

(*Phalaris aquatica* L.), are sown in higher rainfall areas with deeper soils and they are generally included in seed mixtures with annual or perennial legumes.

An alternative use of net primary production of grasslands is represented by the conversion of biomass feedstock into a range of fractions and products for bioenergy and green biorefinery (Bullitta *et al.*, in this volume). The use of grasslands for energy production has been advocated also for Mediterranean marginal environments, but some authors have expressed warnings about this final destination, highlighting that in low-productive grasslands, biomass yield could be insufficient for also satisfying the requirements of forage for livestock production (Peeters, 2009). In South Europe, the interest of grasslands for energy purposes relies on their tolerance to drought, while conventional perennial grasses studied for energy purposes (switchgrass, miscanthus and reed canary grass) have shown strong limitation when grown under rainfed conditions (Scordia *et al.*, 2013). Giant reed seems the only alternative to conventional grasses thanks to a higher drought tolerance, but it shows the great disadvantage being a rhizomatous plant, difficult to eliminate after crop cessation. To this regard, some native perennial grasses widespread in southern Europe were evaluated in the FP7 project OPTIMA for their physiological and productive responses and, when possible, for their ability to be sown by seed (www.optimafp7.eu). *Piptatherum miliaceum* (L.) Coss. seemed the most promising species in Sardinia, thanks to its long growing season and its ability to survive the summer drought. Moreover, smilo grass showed a great potential for the double utilization for winter forage production and summer use for bioenergy (Melis *et al.*, 2016a; Porqueddu *et al.*, 2014).

Key aspects for adaptation to climate change and rehabilitation of grasslands

Climate change, as predicted by a range of climate models, is forecast to have a great impact on agricultural production systems in Mediterranean climates. Several negative effects are expected on grasslands: increased failures at establishment, decreased grassland productivity and long-term persistence, and shortening of the grazing season unless the grassland is irrigated (Del Prado *et al.*, 2014); reductions in desirable grassland species are likely to occur, in favour of species with low palatability and broad ecological niches, due to reduced competition for water and nutrients (Ouled Belgacem and Louhaichi, 2013); nodulation and N-fixation in legumes may become limited by low nutrient supply (especially P and K) and high temperature (Irigoyen *et al.*, 2014). The quality of forbs, grasses and legumes in Mediterranean areas may not be influenced by elevated CO_2, warming and drought under Mediterranean conditions (Dumont *et al.*, 2015). Evidence indicates that changes in climate have occurred historically and Mediterranean ecosystems have shown considerable resilience to these changes (Hopkins, 2012; Seddaiu *et al.*, 2013). In any case, to prevent possible negative effects caused by climate change, increasing the resilience of grasslands and improving forage production and rehabilitating permanent grasslands are now compulsory. In the following sections we discuss the main key-factors that can increase resilience and adaptability and could be considered also as mitigation strategies from climate change.

Sowing annual and perennial species with high summer drought survival

The predicted changes in rainfall distribution, consisting of relatively lower and more variable autumn rainfall and a shorter spring, mean that some or all of the following traits are needed in annual legumes: (1) earlier maturity for reliable seed set in shorter growing seasons; (2) more delayed softening of hard seeds to reduce seedling losses from more prevalent false breaks; (3) greater hardseededness to compensate grassland survival for more frequent seasons of little or no seed set; and (4) a less determinate flowering habit to take advantage of longer growing seasons when they occur (Revell *et al.*, 2012).

In perennial species, desired characteristics include dormancy or low growth during the drought period (Volaire *et al.*, 2013), survival across drought periods (Annicchiarico *et al.*, 2011), and high water use efficiency during the growing season. The concurrent use of plants with different strategies to overcome drought is one of the adaptation approaches proposed by Kreyling *et al.* (2012) to establish permanent and multi-specific grasslands with greater ecosystem stability (Volaire *et al.*, 2013).

Increasing legume utilization

The biological N-fixing activity of legumes contributes to the soil N-enrichment, and this feature could contribute to land rehabilitation of degraded soils, increasing the potential for the re-establishment of native species (Perez-Fernandez *et al.*, 2004). The different species have different efficiencies in fixing atmospheric nitrogen, being 70% in subterranean clover, 90% in lucerne and up to 92% in field beans (Testa and Cosentino, 2009). The amount of fixed nitrogen reaches 184 kg N ha^{-1} $year^{-1}$ in sulla and lucerne (Cosentino *et al.*, 2003; Sulas *et al.*, 2009). In the past, the traditional annual legumes used for grassland rehabilitation were *Trifolium* spp. and *Medicago* spp. Nowadays, many other species belonging to the genera *Ornithopus*, *Vicia*, *Lathyrus*, *Melilotus*, *Biserrula* and *Astragalus* are available on the seed market (Melis *et al.*, 2016b). Most cultivars of these species have been developed from germplasm collected in the Mediterranean basin by Australian scientists (Loi *et al.*, 2008; Nichols *et al.*, 2013). Nonetheless, they showed a poor adaptation to the variable climatic conditions and management systems of southern Europe (Porqueddu *et al.*, 2010; Salis *et al.*, 2012). Native genotypes of these species have also been selected in Mediterranean Europe, but efforts to promote their multiplication in Mediterranean areas have been unsuccessful.

Among perennial legumes, lucerne is the most appreciated species in many farming systems but some limitations to its use arise under rainfed conditions, where lucerne shows a low forage production, limited persistence and scarce tolerance to grazing, requiring the selection of suitable cultivars (Annicchiarico *et al.*, 2011). Currently, other investigations focus on new deep-rooted, drought-tolerant and slow-declining quality perennial legumes, including tallish clover (Hall *et al.* 2013), Caucasian clover (*Trifolium caucasicum* Tausch), stoloniferous cultivars of red clover and more drought-tolerant genotypes of birdsfoot trefoil (Nichols *et al.*, 2012a). Recent research also indicates that *Bituminaria bituminosa* (L.) C.H. Stirt has potential as a perennial forage legume for dry Mediterranean areas (Martínez-Fernández *et al.*, 2012; Porqueddu *et al.*, 2011; Reaside *et al.*, 2013). Other perennial legumes such as sulla (Molle *et al.*, 2003) and sainfoin (Lobón *et al.*, 2015; Theodoridou *et al.*, 2011), are summer-dormant and are already used for their contribution in stabilizing grassland production and forage quality (Re *et al.*, 2014) and for their content of condensed tannins, which can promote amino-acid absorption in the intestine (thereby decreasing nitrogen excretion and reducing greenhouse gas emissions to the atmosphere) and also reduce the load of gastro-intestinal parasites (Piluzza *et al.*, 2014).

Promoting the use of grassland mixtures

The potential agronomic, environmental and economic advantages of sowing mixtures of forage species and cultivars are widely recognised (Finn *et al.*, 2013), especially when mixtures are based on well-adapted genotypes (Dear and Roggero, 2003). Porqueddu and Maltoni (2007) and Maltoni *et al.* (2007) showed that grass-legume mixtures belonging to different functional groups, achieved higher dry matter yields, better seasonal forage distribution, better weed control and higher forage quality than pure stands of each species. More persistent grasslands in LFAs could be also obtained using mixtures of summer-dormant and summer-active perennial species and varieties able to exploit available soil moisture throughout the year (Norton *et al.*, 2012). Mixed swards are also expected to deal better with climatic variability and to show higher resilience (Lüscher *et al.*, 2014). Some problems arise when mixtures are needed to improve the herbaceous layer under a tree canopy, as happens in many woody pastures in marginal regions of the Mediterranean area, where herbaceous species cope with shade and resource competition with trees. In fact, legume abundance generally decreases beneath tree canopies (Marañon *et al.*, 2009). At the moment, specific mixtures for silvopastoral purposes are not available. Some recent experiences in Portuguese *montado* and in Sardinian oak woodlands are being carried out in the framework of the FP7 project AGFORWARD aimed at identifying legume species capable of persistence, and to fix adequately atmospheric nitrogen and to tolerate tree shading and grazing pressures in different Mediterranean pedoclimatic conditions. Preliminary results obtained by the sowing of biodiverse permanent mixtures rich in legumes in Portugal (Aguiar *et al.*, 2011) and mixtures of autochthonous pasture grasses and legumes in Sardinia are available (Franca *et al.*, 2016).

Benchmarking grassland typologies to improve the management of pastoral resources

Within an overall context of climate change, adaptation responses in the annual growth cycle of grasslands species are prompting a range of management-practice adaptations (Ergon *et al.*, 2016). Thus, knowledge of grassland typology is needed to adopt the best management practices; in fact, the differences in vegetation and phytosociological associations are still relevant in LFAs. Agronomic typologies based on the forage value of dominant or reference species, or synthetic indexes were designed in different countries, and recently, a first attempt to synthesize and homogenise grassland typologies at plot, farm and regional level in the different EU states was done by Peeters (2015). With regards to grazing, the extent and intensity of grazing differ among vegetation types and geographical locations (Casasús *et al.*, 2013). Among methods utilized by technicians and extension services for grassland typology assessment, the pasture-type approach, based on the determination of the Pastoral Value (PV) of grasslands, has been applied in several Mediterranean, Alpine and Apennine areas, with the main goal of characterizing pasture vegetation and its potential carrying capacity (Argenti and Lombardi, 2012; Re *et al.*, 2014). This approach may play an important role in defining the management of LFAs, particularly in territories affected by land abandonment and strong grazing pressure, where multiple-benefits of Mediterranean grasslands might be seriously jeopardized. It is based on the concept of pasture type, which could be defined as a semi-natural vegetation (mainly exploited by grazing animals), rather homogeneous in terms of botanical composition and influenced by environmental factors and agro-pastoral management. However, these methods show some limits, due to the fact that they are either too general or too specific and do not combine ecological and pastoral dimensions. A new promising method (Mil'Ouv) was recently developed for the environmental conditions of southern France (Garnier *et al.*, 2016). This diagnosis method is based on a multiscale analysis that considers farm, management unit and topo-facies, highlighting the fundamental interest in integrating local practitioner knowledge into comprehensive and collaborative ecological-pastoral strategies.

Extending forage availability

The traditional transhumance from the plain to the hills and mountains was the most common practice to overcome forage shortages in summer or winter, but in many areas it has almost disappeared (Azcárate *et al.*, 2013). Nevertheless, it is still core to the sustainability of many farms in the Iberian peninsula (Oteros-Rozas *et al.*, 2012). According to Velado Alonso and Gómez Sal (2016), the new transhumance model of short movements has demonstrated flexibility and adequacy to the current condition, and indeed it presents an opportunity to develop a transition towards more sustainable systems. Short distance transhumance has potential to be integrated into multifunctional grassland-based systems in LFAs, e.g. by reducing biomass to prevent summer wildfires. Other alternative solutions to transhumance have been proposed. They include the intensification of agriculture, but in LFAs this model weakens the sustainability of farms (Darnhofer *et al.*, 2010). Thénard *et al.* (2016) identified four self-sufficiency patterns and a set of 20 indicators for dairy sheep farms in southern France, which addressed agronomical and environmental features. These authors found that the use of wide diversity of meadow and species increases the concentrate sufficiency. The exploitation of alternative forage resources could also be a strategy to cope with seasonality of forage production. Shrubs, foliage and acorns from trees are traditionally used in oak-based woodland grasslands as forage supplements or for browsing in some parts of the Mediterranean basin (Papanastasis *et al.*, 2009). Alley cropping based on leguminous shrubs (*Medicago arborea*, *Chamaecytisus palmensis*, *Acacia* sp.) and other species (i.e. *Atriplex* spp.) is a promising way to overcome seasonal shortage of forage in the more semi-arid areas (Norman *et al.*, 2010) but the integration of shrub species into existing farming systems is not straightforward due to the long period of establishment and high implantation costs of shrubs, so nearly no implementation at farm level has yet occurred in southern Europe. In other areas with Mediterranean climate (Western Australia), summer-active C4 sub-tropical perennial grasses (e.g. *Pennisetum clandestinum*, *Chloris gayana, Megathyrsus maximus*) have been successfully introduced. However, their potential use appears very limited in Europe (i.e. risk of introduction of alien species).

Can ecosystem services provided by grasslands represent a tool for supporting pastoral systems in LFAs?

Greenhouse Gas (GHG) emissions and extensive grassland-based systems

Grassland-based farming systems produce not only the roughage, but also a large part of the animal's feed. Most rely on some purchased inputs, such as fertilisers and supplementary feed, and they always use direct energy derived from fossil fuels (Soussana *et al.*, 2010). From a global change perspective, managed grasslands contribute to anthropogenic GHG emissions due to the effects of the livestock raised (Gerber *et al.*, 2013) but they also have the ability to sequester carbon (C) due to plant activity, thereby partly offsetting C emissions (Fornara *et al.*, 2016). The effects on GHG emissions of the intensification/extensification level of livestock farming systems are again being discussed by scientists (Sintori, 2014). The low input techniques related to grassland, requiring less fertilization and field operations than arable land, have lower environmental impacts from eutrophication, acidification, greenhouse gas emissions and non-renewable energy use on grassland-based farms (Rotz *et al.*, 2010). Batalla *et al.* (2015) estimated average values for carbon footprint of sheep milk production systems in Northern Spain as ranging from 2.0 to 5.2 kg CO_2eq kg^{-1} Fat Protein Corrected Milk (FPCM), depending on the level of extensification. Life cycle analysis (LCA) is the standard method to measure the carbon footprint of a product. However, its application to extensive grassland-based systems has a number of shortcomings (EIP-AGRI Focus Group on Profitability of Permanent Grasslands, 2016). Recently, a LCA approach has been utilized to evaluate the environmental performances of sheep farms (Ripoll-Bosch *et al.*, 2013; Vagnoni *et al.*, 2015). Among others, the LCA demonstrated that the substitution of crops such as irrigated maize and wheat with grasslands improved the overall environmental performances of the farm, but only to a minor extent, because of the predominant effect of enteric fermentation with respect to other impact factors (Vagnoni and Franca, pers. comm.).

Environmental policy tools and grasslands

Different environmental policy tools have been implemented to preserve Mediterranean grasslands in a sustainable way. Among them, Natura 2000 is a pan-European initiative started in 1992 with the aim of ensuring the long-term survival of highly valuable and threatened species (fauna and flora) and habitats, listed under both the Birds Directive and the Habitats Directive. In 2015, 18% of the EU28 land area was protected either as Special Areas of Conservation or Special Protection Areas. This proportion rose to 37% in the case of predominantly Mediterranean countries (Cyprus, Croatia, Greece, Italy, Spain, and Portugal). This region harbours 146 different habitat types (more than half of those listed in the Habitats Directive), 37 of which are endemic (Sundseth, 2009), from dry forests (oaks in *dehesas/montados*, black pine forests), scrublands (*maquis, garrigue*) to a large variety of grasslands (dry, calcareous, steppe or mountain grasslands). This programme involves active management of Natura 2000 sites, where the compatibility of agriculture and livestock farming with nature conservation has been achieved through the implementation of agri-environmental schemes. To provide a sound basis for policy making, the LIFE programme has financed a large number of projects aiming to establish the best farming practices to maintain or enhance the natural value of sites (Silva *et al.*, 2008). However, LFAs are very weak in terms of political influence and grassland-based systems are victims of the lack of coordination of agricultural policies with environmental ones. For this reason, problems among farmers and park managers of damage to grasslands and livestock from the wild animals in protected areas and in their surroundings are not uncommon (Fernández-Gil *et al.*, 2016). The ultimate aim of these policies is to encourage the development of sustainable farming systems, where farmers obtain their incomes from animal production but are also rewarded by their supply of public goods that do not have a market price (Bernués *et al.*, 2011), the so-called non-provisioning ecosystem services.

The provision of ecosystem services by European farming systems have been analysed both in permanent grasslands (Huyghe *et al.*, 2014) and wood pastures (Plieninger *et al.*, 2015), highlighting their multifunctionality. It has been proposed that conserving what is left is more effective than getting back to what has been lost, and consequently biodiversity conservation is more likely to be effective on farmlands that are already managed at low intensity and that retain a certain amount of semi-natural vegetation (Kleijn *et al.*, 2011). Their role in regulatory processes with global impact is also substantial, given that the sequestration of soil carbon in grasslands holds a potential for greenhouse gas mitigation (Soussana *et al.*, 2010), and can be reinforced by specific practices such as reducing farm C losses or fire risk (Bullitta *et al.*, in this volume), particularly important in the Mediterranean context. The sociocultural values of these systems are associated with cultural identity, because they are a reservoir of traditional knowledge and result in products that can be differentiated according to their origin or quality, and also with landscape aesthetic values, which can result in opportunities for recreation and tourism. The relative importance of these ecosystem services may be perceived differently by different members of society: interestingly, farmers tend to have a deeper instinctive knowledge about them, especially of regulation and supporting services associated with their farming practices, whereas non-farmers show more global concerns related to mostly to provision and cultural services (Bernués *et al.*, 2016).

Euro-Mediterranean regions are applying different strategies for supporting grassland-based livestock systems. In particular, in relation to the use of agro-environmental measures of the Rural Development Programme (the second pillar of the CAP) in the previous decade (2000-2010) a different positioning of the pastoral farms in relation to the rural development was shown: i.e. relatively aggressive positioning by French Mediterranean regions for the sheep sector, but more timid or almost non-existent by others. This is related, of course, with the ability for mobilization of the profession, with the influence of the various 'lobby' (agricultural, environmental, etc.), with the role and expectations of public authorities and with the willingness of farmers themselves to engage in certain innovative forms of contract (PASTOMED, 2007).

Branding high quality products of grassland-based systems

The optimization of the economic performance of extensive livestock systems can also be achieved by increasing the added value of products. Consumers are increasingly concerned about environmentally-friendly and ethical livestock (i.e. animal welfare) production and product nutritional quality (Bernués *et al.*, 2012; Moreno *et al.,* 2014), and there is evidence that pasture or forage-based diets can improve environmental, ethical and human health outcomes, especially when compared with that from feed-lot systems (Entz *et al.*, 2002; Tsiplakou *et al.,* 2008). Available results suggest that there is an opportunity for products of a superior quality from systems that include a high proportion of forage (Acciaro *et al.*, 2016; Blanco *et al.*, 2012; Zervas and Tsiplakou, 2011). In countries such as France and Italy, the specific natural qualities of individual 'terroirs' define not only the agronomic conditions of production but also the distinctive taste and consumption experience associated with the product. Moreover, grassland-based Mediterranean farming systems located in LFAs can easily evolve to organic (Zoiopoulos and Hadjigeorgiou, 2013), thus leading to a higher valorisation of the products and having a greater capacity to meet the requirements of 'organic' consumers.

Management practices have influence on different quality traits and the main challenge for the farmers is to ensure a constant product quality (Coppa *et al.*, in this volume). In fact, there are strong seasonal changes in the grasslands both in terms of phenology and botanical composition during the growing season (pasture shortage during summer), fluctuations between years and also the need to switch to a diet based on conserved forage or even on concentrates in winter. However, especially in small-scale enterprises, the lack of a reproducible standard in seasonal production could be considered a positive characteristic of uniqueness.

Even if grasslands are highly appreciated for their production of local high-valued animal products (Bernués *et al.*, 2015), at present the market-share of branded grassland-based products is not fully exploited. A validated method to assess and certificate the permanent grassland-based origin of milk and meat products, i.e. through the identification of biomarkers and their traceability from pasture to the final product, is compulsory (Danezis *et al.*, 2016). These biomarkers might represent a proof of the geographical identity of milk, cheese and meat and can be used for developing value chain valorisation, through labels such as Traditional Speciality Guaranteed (TSG), Protected Geographical Indication (PGI) or Protected Designation of Origin (PDO). Currently available authentication methods to distinguish, discriminate or authenticate milk, cheese or meat according to the management practice and constraints to their implementation in routine authentication were summarised by Coppa *et al.* (in this volume). In the end, consumer's willingness-to-pay for the products is necessary to ensure an adequate remuneration to the farmers.

Conclusions and future directions

Grasslands, often with different degrees of tree or shrub cover, still have an important economic and social role in Mediterranean LFAs. Currently, they face several constraints that require a holistic approach to be overcome, the farming systems being quite complex and not specialized. Unfortunately, most studies have focused on the effects of only one or a few influential factors on the grasslands without considering others that may play a relevant role on the system. Currently, some agronomic objectives need to be satisfied. The development of new varieties of grassland species for dry Mediterranean areas and multi-site investigations are needed to identify the best adapted grassland species along with the most appropriate grazing management. However, the successful development of a forage and pasture seed industry in the Euro-Mediterranean countries is critical to guarantee seed supplies of the best-adapted cultivars to the region.

In order to be able to compete with products coming from intensive agriculture, both public perception and the management schemes about LFAs should urgently be reoriented. Management and rehabilitation should be conducted in a participatory manner involving all stakeholders using a territory, and institutional and policy support is needed, in addition to technical aspects, for the sustainability of grassland resources. For this reason there is a rising demand for scientific knowledge and new approaches in scientific research aimed at:

- developing farming systems based on the use of local breed and forage resources, where the most adequate management techniques are implemented for optimal technical and environmental performance and the delivery of products with high added value;
- promoting the involvement of farmers in the assessment of experimental field trials to communicate scientific results and obtain a qualified feedback for future research needs;
- strengthening the connections among research and practice, by means of efficient brokering systems and facilitator agents, whose role is nearly unknown in Mediterranean areas;
- developing innovative management tools that may constitute an integrated system of support for decision (DSS) making in extensive grassland-based farming systems.

The training of young specialized pastoral agents for rural land planning (i.e. synergies among farms and regions located in the more fertile areas and the marginal areas) and new immigrated workers (technical graduates, experienced people specialized in all aspects of grazing: social, land, environment, animals, etc.) could also be a way to help the management of LFAs and they should be involved in the technical boards of protected areas.

Long-term multidisciplinary experiments are also needed to continuously check the pastoral resources, environmental outputs and ecosystem services associated with Mediterranean grasslands, in order to provide a better understanding of the complexity of grassland ecosystems and to define specific indicators for better management decisions and mitigation of climate change. Also, the integration of data sets at local level is necessary, aimed at implementing the LCA tools for interconnecting extension services to academic and research centres and, thus, obtaining a more timely and accurate dynamic picture of the territorial context. Such an approach might facilitate the creation of territorial management permanent committees of stakeholders, where farmers should participate directly in such committees and be effective in identifying and maximizing all the opportunities for multifunctional benefits.

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Edited by

C. Porqueddu
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Theme 1.
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