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SUMMARY – The traditional role of grasslands has been, until recently, to support livestock production. This has expanded to other aims, particularly in the environmental domain. Grasslands are important contributors to biodiversity both within the Mediterranean Region and elsewhere. Emblematic species, such as the great bustard (*Otis tarda*) and the Iberian lynx (*Lynx pardinus*), are dependent on the occurrence of grasslands within their regions of distribution. The relevance of grasslands to biodiversity is recognized by the European Union with grassland areas being classified as priority habitats within the Natura 2000 network. Contribution to biodiversity occurs at scales varying from the community to the landscape. Other functions of grasslands include carbon sequestration, recreation or even protection, e.g. as fire-breaks against wildfires. The main functions of grasslands beyond livestock production are described with a particular emphasis on Mediterranean grasslands and their contribution to biodiversity.

Keywords: Grasslands, biodiversity, nature conservation, environmental services, Mediterranean.

RESUME – *"Le rôle multifonctionnel des pâturages". Les pâturages ont été envisagés, depuis longtemps, presque uniquement dû à leur rôle dans l'alimentation animale. Cependant, dans les dernières années, on a reconnu aussi que l'intérêt des pâturages est très diversifié et lié à d'autres domaines, en particulier au niveau de l'environnement. Ainsi, les pâturages jouent un rôle important vis-à-vis de la biodiversité soit dans la Région Méditerranéenne, soit ailleurs. Des espèces très rares et très caractéristiques telles que l'outarde (*Otis tarda*) et le lynx Ibérique (*Lynx pardinus*) dépendent du maintien des pâturages dans les domaines de sa distribution. L'importance des pâturages pour la biodiversité a été bien reconnue par l'Union Européenne, avec la classification des habitats prioritaires dans le Réseau Natura 2000. La contribution des pâturages pour la biodiversité peut être analysée, soit à petite soit à très large escale (du niveau de la communauté jusqu'au niveau des grands domaines). D'autres fonctions importantes des pâturages comme la séquestration du carbone au niveau du sol, les aménités rurales, l'effet de protection contre les feux, la régularisation du cycle de l'eau, parmi d'autres, sont aussi rapportées dans ce travail.*

Mots-clés : *Pâturages, biodiversité, nature, conservation, multifonctionnalité, méditerranéenne.*

Introduction

Grazing is a land use covering approximately 3300 million ha (more than 25%) of the global land surface which makes it the largest and most extensive land use of the planet (Asner *et al.*, 2004).

The countries with most land area in grazing systems are Australia, 440 million ha; China, 400 million ha; United States, 240 million ha; Brazil, 170 million ha; and Argentina, 140 million ha. Mongolia, Botswana and Uruguay are the countries with the highest proportion of land allocated to grazing (80%, 76% and 76%, respectively). Countries with the highest stocking rates are Malaysia, 3.2 Animal Units (A.U.) ha^{-1}; India, 2.7 $AU.ha^{-1}$; N. Korea, 2.1 $AU.ha^{-1}$; and Vietnam, 1.8 $AU.ha^{-1}$; with others with relatively high stocking rates to be found in central Europe and the Middle East. Usually those countries with large areas of dryland grazing systems (e.g. Australia, Argentina, and the United States) have relatively lower stocking rates (Asner *et al.*, 2004).

In Europe, grasslands are a dominant land use covering approximately 80 million ha, or 22% of the land area of the European Union (EU25) (EEA 2005), and sustain 150 million cows and 150 million sheep, which is nearly 15% of the global animal population (FAO 2004 in http: //www.faostat.fao.org.). Extensive areas of permanent grasslands characterize the countries dominated by a Mediterranean climate, including Portugal, Spain, Italy, Greece, most of southern France and part of Turkey.

Grasslands have traditionally been used all around the world for grazing and livestock production generating products such as milk, meat, fiber and others.

Soils and climate, particularly the total and seasonal distribution of rain, affect the level of biomass production among different regions. In Europe, the most productive grassland areas, located in northern regions, are dominated by perennial species and winter, with low temperatures and often snow cover is the main season of nutritional constraint for livestock production.

In the Mediterranean regions of the world: Central California and Chile, South-western Australia, southern South Africa and the Mediterranean basin, the climate is characterized by mild and wet winters and, particularly, long summer droughts, which impose nutritional constraints toward the end of summer.

Mediterranean grasslands: constraints on herbage production

High annual inter- and intra-variability of rains are, along with prolonged summer droughts, a characteristic of Mediterranean regions. Wide variations in amount of herbage biomass from one year to the next are common and a direct result of fluctuations in precipitation and temperature (Pitt and Heady 1978). Such variability imposes limitations not only on herbage production but also influences the botanical composition of grasslands (e.g. ratio of grasses and legumes) from year to year (Levassor *et al.*, 1993).

In the Mediterranean Basin, most grasslands area characterized by annuals that spend the period of high summer temperatures and lack of moisture in the soil buried as seeds waiting for the first rains to germinate (Espigares and Peco, 1993; Archibold, 1995; Seligman, 1996).

The typical cycle of herbage production in the Mediterranean begins with germination and herbage growth during autumn. The cool winter temperatures halt vegetation growth until temperature starts to rise again in late February and March. Warmer spring temperatures, together with moisture that has accumulated in the soil during the wet winter causes the typical Mediterranean spring herbage flush.

Temperature and precipitation interact with time of germination of seeds of annual species and determine the amount of herbage available later in the season. If germination occurs early in autumn, when temperatures are still high, forage availability is higher as compared to a year when germination occurs later in autumn or when temperatures are lower and less favourable for plant growth (Murphy 1970).

The nutritional characteristics of the herbage layer can thus be summarized as: low availability and quality towards the end of summer, high availability and relatively high quality in spring, high availability but low quality in summer, and a period of nutritional constraint from summer towards autumn and occurrence of first autumn rains (Seligman 1996). Constraints in the seasonal quality and production of herbage make browse a relevant ruminant staple food in many Mediterranean systems (Le Houérou, 1980; Bugalho and Milne, 2003).

Beyond animal production: the biodiversity of mediterranean grasslands

Mediterranean grasslands are characterized by high plant species diversity. For instance, Dias-Villa *et al.* (2003) reported 113 different plant species within 0.1 ha plots located in grasslands under evergreen oak cover in Spain. High grassland diversity may affect positively herbage production and stability through complementarity and facilitation processes among species (Hector *et al.*, 1999; Caldeira *et al.*, 2001; Caldeira *et al.*, 2005).

Moreover, it has been shown that high species diversity within grasslands is essential for adequate provision of a set of environmental services such as nutrient cycling, decomposition, productivity and water storage (Hector and Bagchi, 2007).

In the Mediterranean Basin, diversity extends from the local plant community to the whole landscape. The Mediterranean is characterized by a long history of interaction with man (DiCastri *et* *al.*, 1981). Many species evolved adaptations to disturbances, such as grazing and fire, and need such disturbances to occur in the community. Grasslands in particular need clear cutting, grazing or fire to be maintained or shrub communities will rapidly dominate and out-compete the herb layer (Leiva *et al.*, 1997).

Different types and levels of disturbance create a diverse mosaic of habitats. The coexistence of different land uses generates a highly diverse Mediterranean landscape within which grasslands are an important component.

Beyond plant diversity, Mediterranean grasslands support a species rich fauna. In Portugal and Spain, for example, grasslands constitute an important habitat for several endangered bird species. The Castro Verde region of southern Portugal, for example, is a Special Site for Bird Protection characterised by grasslands and fallow lands where different birds of conservation value occur: Great Bustard (*Otis tarda*), Lesser Kestrel (*Falco naumanni*), Little Bustard (*Tetrax tetrax*), Calandra Lark (*Melanocorypha calandra*), Black-Bellied Sandgrouse (*Pterocles orientalis*) and raptors, such as the Hen Harrier (*Circus cyaneus*), are common and dependent on the maintenance of a grassland-type habitats for their occurrence.

The shrub- grassland matrix is also a fundamental habitat for the most endangered felid in the world, the Iberian Lynx (*Lynx pardinus*), and its prey, the rabbit (*Oryctolagus cuniculus*), and other mammals of conservation value (e.g. Wild Cat *Felis sylvestris*).

Within Natura 2000 – a pan-European network of protected areas - grassland *per se* or within other areas are classified as priority habitats. For example, the Portuguese evergreen oak *montados* or Spanish *dehesas* silvopastoral systems, with their typical grassland component, are priority habitats under the Natura 2000 Network. The typical mosaic structure of such systems, varying in the proportions of grassland and shrub cover, as well as tree density, has a typicalyl high horizontal and structural diversity benefiting a range of different species. Raptors, such as the threatened Imperial Eagle (*Aquila adalberti*) and Black Vulture (*Aegypius monachus*), nest in *montados* and *dehesas* and use the open grassland patches for feeding.

Other environmental services

Carbon sequestration

The carbon balance in terrestrial ecosystems is determined by the difference between inputs from primary production and the return of carbon to the atmosphere through decomposition of organic matter (Austin and Vivanco, 2006). As a consequence, processes contributing to positive balances between production and decomposition may contribute to carbon sequestration.

The role of grasslands in carbon sequestration was recognized recently (Hu *et al.*, 2001). An experiment conducted in an annual Mediterranean Californian grassland in which different plots were subjected to ambient (360 ppm) and increased (720 ppm) CO_2 concentrations has shown that by the end of the sixth year of the experiment, plots exposed to increased CO_2 exhibited a moderate increase (2750 g Cm^{-2}) in the soil stock of organic carbon (e.g. soil, debris, roots) as compared to control plots (2612 g Cm^{-2}) (Hu *et al.*, 2001). The researchers suggested that the higher concentrations of CO_2 stimulated plant growth and reduced the nitrogen available for the soil microbes diminishing their capability to decompose dead plant material. Because of lower decomposition rates, less carbon was released to air as CO_2 from microbial respiration.

According to same study, however, the carbon accumulated in grassland soils may be limited as lower rates of plant decomposition could reduce the supply of nitrogen for additional plant growth. Grasslands may act as carbon sinks, at least in the short-term, as far as processes that induce litter decomposition, such as soil mobilization, are limited.

The potential of grassland soils as carbon sinks, however, may be difficult to maintain in relation to predicted climate change scenarios such as higher frequency of droughts or heatwaves (Ciais *et al.*, 2005; Soussana and Luscher, 2007). Indeed, it was shown that during the world heatwave in 2003 permanent grasslands located in Hungary changed from carbon sinks (-188 g C m^{-2}) to carbon sources (+ 80 g C m^{-2}) (Nagy *et al.*, 2007).

Finally, the role of soil grasslands as carbon sinks needs to be balanced with that of methane emissions by ruminants. Ruminants contribute approximately one-third of the global anthropogenic emissions of methane (IPPC 2001). Extensive animal production systems, such as those occurring in several grassland types, makes a relatively lower contribution to methane production as compared to more intensive livestock production systems (Subak, 1999). Some authors also suggest that condensed tannins present in a number of grassland species, such as trefoils (*Lotus* spp.), can improve protein digestion, reduce bloat and potentially diminish methane emissions by livestock (Hopkins and Holz, 2006).

Other services

Grasslands and associated shrub vegetation may contribute to the retention of soil water, a reduction in run-off and diminished soil erosion. The effect of grasslands on fine-scale redistribution of sediments through run-off has been documented (e.g. Mcivor *et al.*, 1995). Under climate changes scenarios that predict an increased frequency of high intensity rainfall and more events leading to downstream flooding, the positive role of grasslands in mitigating such events may increase (Hopkins and Holz, 2006).

In the Mediterranean, grasslands have a role in fire prevention. Rural abandonment in many areas of southern Europe is leading to the development and dominance of shrub formations (e.g. *Cistus* spp. in Iberia), increasing vegetation fuel load and the hazards of fire. Frequently, extensive woodland and shrub vegetation (e.g. maquis) are interrupted by areas of grassland or pasture which act as effective barriers against propagation of wildfires. Maintenance of open grassland areas is thus essential to maintain landscape heterogeneity and a potential tool to mitigate the risks of wildfires.

Grasslands also play important roles in recreation. Many outdoor activities, such as bird-watching, hunting, walking and general enjoyment of nature, are linked to open landscapes and extended views. A study by Henkin *et al.* (2007), for instance, concluded that open landscapes induced by grazing by goats or cattle provide easy accessibility (e.g. trail walks and picnics) as well as extended view towards the distant landscape, making these areas more interesting for human enjoyment.

Threats

Grasslands, in particularly Mediterranean grasslands, are under different threats. In the European Union (15 member states) permanent pastures decreased by 17% or 9.61 million ha between 1971 and 2001 (EEA 2005). Land conversion from grazing to other primary uses (e.g. agriculture and forestry) is a widespread threat that may even result from agricultural policies. Until recently, the Common Agricultural Policy of the European Union provided subventions for the afforestation of agriculture land including fallow land and grasslands. Conversion to urban use is also a common threat. In contrast, rural abandonment and lack of management, is inducing shrub encroachment leading to disappearance of many grassland areas. The maintenance of grasslands needs periodical disturbance of the plant communities through cutting, fire or grazing (Leiva *et al.*, 1997). Once levels of disturbance stop, plant succession leads to shrub encroachment and loss of grasslands. Shrub encroachment is indeed a global problem affecting many of the world grasslands (Briggs *et al.*, 2005). Predicted climatic changes may also result in expansion of dry and arid grassland types (even in desertification), for instance, in some parts of southern Europe.

Conclusions

Grasslands and grazing lands are a dominant land use globally. Patterns of grassland production differ among regions. Primary productivity of Mediterranean grasslands, for instance, is constrained by typical prolonged summer droughts potentially affecting animal production. Mediterranean grasslands, however, generate high levels of biodiversity and a range of other environmental services and amenities. Threats, ranging from land use conversion to abandonment, lack of management and shrub encroachment, are endangering the future of grasslands. Valuation and implementation of mechanisms for Payment of Environmental Services, possibly similar to those already in use in some forest land uses (Pagiola *et al.*, 2002), may potentially contribute to the economic sustainability and future conservation of grasslands and their multifunctional role.

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