

GRAZING SYSTEMS AND BIODIVERSITY IN MEDITERRANEAN AREAS: SPAIN, ITALY AND GREECE

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SUMMARY

Large Scale Grazing Systems (LSGS) are much more than large expanses of semi-natural vegetation. LSGS are complex structures emerging from the interaction of human behaviour and natural resources. Man-made and nature laws are intertwined in systems of grassland management to produce large-scale effects. LSGS actually harbour a significant part of European natural values, but are also places where a small part of the rural population strives to make a living under harsh environmental and social conditions. This research is aimed at responding to what is left behind under current trend (abandonment). We have dealt with identification, analysis and diagnosis, but not with prescription. Our main argument is that extensive grazing is congenial with natural values, but is the former that gives way to the latter. This assumption was tested for the main LSGS of three Mediterranean countries of the European Union (EU): Spain, Italy, and Greece. Survey tools (fact-sheets, survey guidelines and sustainability questionnaires) were devised within the EU-funded LACOPE project and further, groups of external experts, within the three countries, were requested for collaboration. This research encompasses two parts. In the Presentation section, the most representative LSGS in Spain, Italy and Greece were identified and a comparative typology elaborated based on individual profiles for external experts. The Successional Trajectories and Target Vegetation types sections are devoted to the relationships between grazing and biodiversity, as assessed by plant species richness and vegetation

types. In this case, external experts' contribution, literature review and further co-operative and interdisciplinary job were used. We detected general patterns of shrubby overgrowth on grazing cessation, increasing species richness with extensive grazing and plant species adapted to grazing or post-grazing succession. The relationship between grazing and biodiversity was not univocal, and spatial and temporal management of grazing play a major role. It must be stressed the importance of adequate knowledge of the species and habitat specific impacts of grazing regimes (temporality and grazing intensity). LSGS in the three countries face some common threats from intensification in the lowlands to abandonment in the far-reaching and less favoured grazing grounds. Harsh workings conditions, social fragility, lacks of assurance of family business turn over, and poor economic performance, are common drivers of change, under a global setting of economic development. However, differential diagnosis of these constraints and alternative management practices (prescription) at the regional level are further required in devising and implementing sensible grazing management plans and policy frameworks.

Keywords: Agriculture and environment, profile of large-scale grazing systems, successional trajectories, habitat types, conservation target species, high nature value grasslands, rural development.

INTRODUCTION

Extensive and Large Scale Grazing Systems (LSGS) represent one of the best-adapted land uses in marginal rural areas of the European Union (EU). Moreover, some of the Less Favoured Areas (LFA) can only be maintained through lively animal farming of locally adapted livestock. LSGS represent landscape expanses, where land-based livestock farming is the dominant productive activity, and have been considered of significant importance for nature conservation (Bignal and McCracken, 2000; Dwyer *et al.*, 2002, Clergue *et al.*, 2005) and agronomic services (Hillel and Rosenzweig, 2005). The socio-economic and institutional settings of six European LSGS over a global range of environments have been previously assessed (Caballero *et al.*, 2007). However, a co-operative research is lacking on the identification, description and status of LSGS and on the real environmental trends over particular biogeographical regions of the EU. This research deals with Mediterranean LSGS as represented by three main countries: Spain, Italy and Greece. These three EU countries contain a wide range of biophysical conditions able to represent the most important types of LSGS in the European Mediterranean area. The importance of these areas rests on both environmental as well as socio-economic values. They support outstanding biodiversity, form unique landscapes, are the source

of high-quality food derived from animal production, sustain rural population, and constitute important areas for rural leisure and tourism.

The spatial distribution of LSGS in the Mediterranean basin is primarily conditioned by topography and climate. Within these two criteria, the structure and composition of the plant communities is related to soil conditions and the actions of humans and animals. Actual LSGS in this area are the result of a long history of influence of humans and grazers. As a region of the Temperate Zone, the Mediterranean was largely forested with evergreen and deciduous oaks, pines and mixed forests. The wild animals and natural fires extended the grasslands into the forests. Later on, the arable farmers and pastoralists further expanded the open land (Fillat, 2003).

Air temperatures at the ground level are related to altitude, latitude and the proximity to the seashore. In the case of Spain, a continental Mediterranean type of climate appears in the inland plains and strong contrasts exist from Atlantic to Mediterranean or sub-desertic environments. In the case of the Italian Peninsula, the Mediterranean bioclimate extends along the entire Tyrrhenian area, with the exclusion of a tract of the coastline in Liguria, it continues to the large and small islands, in the Ionian sector and in the Adriatic area up to the Abruzzo region (Blasi and Michetti, 2007). In the case of Greece, most regions fall within the Mediterranean type of climate, altitude and the proximity to the seashore being the main determinants of variations.

With the exception of the Alpine regions in Italy and the Euro-Atlantic and Alpine regions in Spain, the Mediterranean climate is characterized by a hot summer period, which coincides with the lowest rainfall, and a rainy period, which coincides with the lowest temperatures. Two critical periods for the vegetation are apparent, with temperatures and rainfall being the limiting factors, respectively. The duration of the dry period is mostly related to the altitude, varying the sub-regions from supra-Mediterranean (1-2 months of dry period) to thermo-Mediterranean (up to 5 months of dry period according to the Gaussen index). Main environmental and socioeconomic features of Mediterranean LSGS are shaped by these contrasting geophysical conditions. The distribution of LSGS across the Mediterranean region and the characteristics of the main components of each farming system are the result of a long interplay between animals and their habitat shaped by the human intervention.

In fact, environmental (nature-depending) and social and management (man-made) factors are intertwined, therefore the understanding of how the network of people and nature that make up LSGS interact and reinforce each other is the main premise of this research. Grazing management is governed by laws, institutions and farmers' options that, in turns, may affect environmental values. Large-scale effects depend on the underlying laws of people and nature (Fernández-Giménez and Swift, 2003; Caballero *et al.*, 2007). According to this premise, this research represents an interdisciplinary

methodological approach for testing large-scale environmental effects. Although many environmental functions can be related to the management of LSGS (e.g., erosion control, fire risk reduction, soil quality, watershed stewardship, C and N balances), we have focused on the relationship between grazing and plant biodiversity. This latter function is represented by changes in vegetation types and plant species as this important variable may shape other aspects of global environmental change (Brye *et al.*, 2002; Lindborg and Eriksson, 2005; Gervois *et al.*, 2008; Smith *et al.*, 2008).

Another important premise is the possibility of changing the spatial scale distribution for future policy schemes. The EU Commission intends to identify High Nature Value (HNV) farmland across Europe (Oñate, 2005; RDP, 2005; IEEP, 2007). This goal is the main justification of Natura 2000 or LFA schemes (EC, 2004). The first relies mainly on the habitat/biotope perspective. The second is designated by the EU Commission based on natural handicaps on land productivity or remuneration for nature conservancy. At the end, land use is the main determinant of natural values. However, land uses are not directly linked to these two latter schemes, but to particular farming systems with their corresponding farmers and stakeholders. It is within this context that the basic fabric of rural society and economic activity is maintained and, more important, it is within this framework that the main weaknesses and strengths can be unveiled. The idiosyncrasy of farmers and farming activities suggests a need for establishing a mixed agriculture-environment body. Working at the system scale allows an interdisciplinary approach, a quality not well entrenched under the other two schemes. For example, in Spain and Greece some 80% of the country is designated as LFA. However, it is hard to unveil the many subtleties of the Spanish or the Greek rural life under this broad scheme.

The LSGS are mainly located in the LFA of the European Union (EU), where the conventional intensification path of development, through private capital investment and low labour-demanding operations, is limited by environmental and social constraints. Left to their own or under insensible schemes of policy support, the abandonment trend can be more apparent than the intensification threat (Hadjigeorgiou *et al.*, 2002; Kristensen *et al.*, 2004; Hadjigeorgiou *et al.*, 2005). We want to test this trend across a global range of Mediterranean environments and further to assess whether or not is affecting to some environmental values. These systems are supported on the ground of potential delivery of agronomic services and environmental assets, but no longer can these assumptions be taken for granted. If it is not the case, questioning the effects of current schemes of EU policy support can be derived (Marriott *et al.*, 2004).

Although an important objective of this research was to produce national maps of Mediterranean LSGS, we should be aware that many interesting data, which are not mappable, could nonetheless be very informative (Jones, 2005). Data contained in the Presentation section should be considered as a primary source of information, justifying

the inclusion of individual LSGS types in national maps and assessment of large-scale environmental effects in further sections of the paper.

The general objective of this collaborative research was to identify LSGS across the Mediterranean area of the EU, where HNV farmland can be present. In this sense, LSGS are considered as those areas in Europe where extensive livestock systems are the dominant land use at a landscape scale. This land use support is associated with either a higher species and habitat diversity or the presence of species of European conservation concern or both. In this sense, the research will test, specifically, the relationship between extensive grazing (or cessation of it) and vegetation biodiversity over a global range of Mediterranean pasture landscapes.

MATERIAL AND METHODS

The spatial distribution of LSGS in these three Mediterranean countries has been addressed by a regionalization of the LSGS within each country. The sectoral classification allows for a relationship with corresponding biogeographical regions. Regional categories are justified by distinctive grazing management and lack of interdependence at the core area. However, precise borderlines are difficult to draw at the interface between contiguous LSGS. For this reason, national maps depict LSGS as hot spots. The selection of Spain, Italy, and Greece represents a global range of European Mediterranean environments. In Spain, the Euro-Atlantic, Alpine and Mediterranean biogeographical regions are represented. In Italy, the Alpine, the Continental and the Mediterranean biogeographical regions are represented; while in the case of Greece, the Mediterranean region is dominant. A collaborative effort was requested to a group of national experts within each country. These experts were all pundits with scientific and managerial expertise on their respective LSGS. Our objective was a description of a global range of Mediterranean LSGS that can appear remarkable when taken one by one.

Typology criteria and survey tools

Large Scale Grazing Systems (LSGS) were the focus of the EU-funded LACOPE project (LACOPE, 2002). Detailed ecological and socioeconomic research was carried out on seven LACOPE study areas (Oksanen *et al.*, 2006; Caballero *et al.*, 2007), and further expanded to a broad range of European LSGS. In this latter case, the main objective was to recapture the main European LSGS from anonymity by providing location and description of LSGS sharing a common set of environmental and socioeconomic features at the large landscape scale. LSGS were broadly defined as those grazing systems located mainly in harsh environments and less favoured and

handicapped areas, where extensive grazing is a substantial productive activity that may have an influence on natural values and the stability of the rural population. LSGS represent a community of livestock farmers sharing productive forms, traditions and even cultural values that, in turns, may shape the environment. LSGS may represent a sensible spatial scale when a link between biodiversity (environmental function) and farm economics is looked for in interdisciplinary studies of grazing systems. LSGS are not static structures, but the current dynamic of change through an intensification path (Steinfeld *et al.*, 1998) is somewhat limited by environmental constraints. In this sense, LSGS shared features of extensive and traditional systems, but defined to a more regional and generalized spatial scale. Isolated or interspersed low-input farms, within an intensified environment, barely constitute a LSGS.

Some guiding questions and objectives in expanding the scope of the LACOPE seven study areas were:

- Which LSGS are typical for the different European biogeographical regions?
- How do they share common environmental, economic and cultural functions?
- What is their current state and their main environmental and socioeconomic assets or hazards?
- What is the main dynamic of change and the effects on their main functions?

Under this scope, a quantitative and qualitative set of criteria and indicators were devised for LACOPE partners (Niemeyer and Rosenthal, 2003; Moreira, 2004). Main typology criteria included indicators on geographical location, main habitat types and management units, grazing management, grazing trends and biodiversity, co-operation between stakeholders, and socioeconomic stabilizing and destabilizing factors (Holz, 2005_{a, b}).

These criteria and indicators were structured in three survey tools: the fact sheet, the survey guideline and the sustainability questionnaire. The first two, of increasing range of complexity, were aimed at describing the main structure and functions of LSGS; the third was aimed at assessing how environmental and socioeconomic criteria may interact when analyzing a wide range of LSGS. Data collected in the latter were previously analyzed and reported (Caballero *et al.*, 2008). For the purpose of this research, we will refer to data collection and processing in the Mediterranean biogeographical region as represented by LSGS in three countries: Spain, Italy and Greece.

Framework profile of LSGS

Based on LACOPE survey tools, a common framework profile was devised for identification and description of LSGS in the three countries. The profile encompassed the following criteria:

- LSGS as defined in the LACOPE setting, but including a gradient of intensification even within particular farming systems. At the landscape scale, LSGS is extensive, but overgrazing can be present in particular farming units. Thus, an LSGS does not necessarily involve extensive grazing. Abandonment was considered as the extreme form of extensification.

- LSGS are linked to particular biogeographical regions at the landscape scale. This sectorization of LSGS allows for a relationship of dominant trends in grazing management with the presence or potential changes in vegetation types and plant species, as the EU habitat Directive of relevant vegetation types (EC, 2003) is categorized by biogeographical regions. Vegetation types in LSGS were identified following the phytosociological approach (Westhoff and Van der Maarel, 1978; Rivas-Martínez *et al.*, 2001a, b) as this is a reference for the EU Habitat Directive. Landscapes dominated by fenced plots of cultivated grasslands and devoid of natural or semi-natural vegetation types are not considered as LSGS.

- LSGS are land-based systems in the sense that at least some animal lots are raised under grazing conditions. In most LSGS the grazing season is conditioned by environmental constraints (cold season, dry season), and structural grazing and non-grazing seasons can be defined for different vegetation types and grazing grounds (lowland or upland vegetation types). This fact may represent a gradient of mobility (from sedentary to nomadic forms of pastoralism) and different schemes of access to grazing-rights (from private to co-operative ownership regimes). Frequently, herds/flocks move to different farming units (FU) and grazing grounds over the year within a whole management unit (MU). Composed FU may represent different strategies for intensification and integration of crops and livestock (from purely pastoral units to mixed farming units). Intensification of livestock production may evolve out of both pastoral and mixed farming units and not only out of the latter, as current models of agricultural transition seem to assume (Steinfeld, 1998; Powell *et al.*, 2004). Increase of labour, capital, and/or technology inputs per unit of land and/or animals may apply in both types of units. In our definition, traditional pastoral units are not inherently unsustainable.

-LSGS are endowed with itinerant herds/flocks or particular livestock lots. Mobility and herding patterns are main features of the grazing operation. In this research, the term transhumance is meaning to design the great distance displacement of herded animals along specific drove paths, such as the Spanish *cañadas* and *veredas* of the old Mesta system or the Italian *tratturi* and *tratturelli* of the old kingdom of Naples. Nowadays, the old transhumance system has almost disappeared. Smaller distance and frequently vertical movement of animals is termed as trasterminance or vertical trasterminance. It frequently encompasses movement along grazing grounds of different altitude or between lowland and upland pastures. Regarding herding patterns, taking care of animals

can be permanent or occasional or animals can be unherded for quite long periods (free-range animals). In any case, animals graze areas large enough to ensure free movements and include enough grazing resources to avoid systematic overgrazing of parts or the totality of pastures. Both mobility and herding patterns may have a great influence on vegetation changes.

- LSGS are organized by particular institutional setting, with particular grazing institutions regulating grazing management and different arrangements between main stakeholders (landowners and pastoralists). Differential interactions among stakeholders may give way to different levels of co-operation and social interaction, from social cohesion to social fragility, both within and out of the LSGS.

- LSGS are generally linked to the presence of indigenous livestock breeds, although this criterion is not considered as exclusive. The presence of target vegetation types and plant species or potential vegetation changes are linked by coevolution to grazing behaviour of these breeds. Moreover, the presence of indigenous livestock breeds is a distinction for local livestock products (Boyazoglu and Morand-Fehr, 2001).

Data collection and processing

Within each one of the three countries, representative experts were selected and contacted. In the case of Spain, the representative expert was one LACOPE partner with responsibilities in devising the survey tools. The national network for selecting and contacting external experts was the Spanish Grassland Society. In the case of Italy, the main network was the Italian Society for Agronomy and in the case of Greece, the Greek Grassland Society. External collaborators were selected previous explanation of objectives of the co-operative research action and survey instruments. All external experts were able to identify their LSGS and fill in the corresponding fact sheet. A minority also provided data requested in the survey guideline and the sustainability questionnaire. Data reported in this latter instrument, together with stabilizing and destabilizing factors of the fact-sheet were the basis of a previous research (Caballero *et al.*, 2008). For this research, data collected in the fact-sheet were standardized according with criteria of the framework profile and are the basis of individual profiles of LSGS in the Presentation section. Data collection and processing for individual profiles of LSGS were carried out during the years 2004 and 2005 and further refined by collaborative job to 2009.

The use of common vegetation maps was substantial to locate the LSGS under a single definition of vegetation units. The map of biogeographical regions of Europe (Metzger *et al.*, 2005) was used as main base-map although, in the case of Spain, CORINE-based and topographic national maps were also available for location of LSGS. Main protected areas (National or Regional Parks) were also requested, if included within the LSGS

area, and whether some grassland vegetation types (four-digit code of Natura 2000) are recorded as habitat of community interest in the EU Habitat Directive (EC, 2003). As additional information, the main natural vegetation types, as indicated by the Map of Natural Vegetation (MNV) of Europe (Bohn *et al.*, 2004) were also requested, although not included in this research.

Representative experts grouped LSGS within four geographical sectors of differentiating environmental conditions. In Spain: Euro-Atlantic, Pyrenees, Inland Sierras, and Inland Plains. In Italy: Northern, Central, Southern and Sicily, and Sardinia. In Greece: Mediterranean mountains, Mediterranean North, Mediterranean South (mainland) and Mediterranean South (islands). Types of LSGS within sector were described for the corresponding external experts, 15 in Spain, 14 in Italy and 10 in Greece, although some LSGS from Italy are mainly sub-types, only differentiated by their main productive orientations or livestock grazing species.

Habitat types and biodiversity

There is a broad variety of links between grazing and biodiversity (Milchunas and Lauenroth, 1993; Steinfeld *et al.*, 1998; Niemeyer and Rosenthal, 2003; Rook *et al.*, 2004). A trend towards abandonment of grazing grounds in the LFAs of the EU has already been reported (Brouwer *et al.*, 1997; Caraveli, 2000; Kristensen *et al.*, 2004; Vicente-Serrano *et al.*, 2004; Roeder *et al.*, 2007) and further confirmed in LACOPE study areas (Caballero *et al.*, 2007). Our main environmental goal in this research was to test this trend in a broader range of Mediterranean environments; and how this trend may affect biodiversity as valued by two main processes: vegetation succession and target vegetation types and species as rated by the EU Habitat Directive.

Most grassland landscapes in Europe, except for few in the arctic and in most arid Mediterranean regions, are the result of human intervention and livestock grazing. Under abandonment, post-grazing succession takes hold with short-term and long-term vegetation changes (Taillefumier and Piégay, 2003; Vicente-Serrano *et al.*, 2004). In the Mediterranean region, post-grazing succession towards either shrubby or further on Mediterranean forest is documented (Debussche *et al.*, 2001; Ispicoudis and Chouvardas, 2005), although the effects of grazing abandonment on species richness and target vegetation types in a broad range of Mediterranean environment have scarcely been described. In some cases, target plant and animal species, which are rare in a European context, will be considered as depending directly or indirectly from grazing use in specific LSGS. In a broad sense, some grassland vegetation types linked to grazing use, such as those contained in the EU Habitat Directive, can harbour some endemic rarities. In other cases, such as in the cereal-sheep farming system of Castile-La Mancha

(Spain), the LSGS is linked to arable land use and maintenance of open landscapes is more important than vegetation types for endangered steppe birds such as Great Bustard (*Otis tarda*).

After main LSGS were identified, described and mapped, data collection and processing for ecological functions (successional trajectories and target species and vegetation types) were recorded in the years 2005 and 2006. For this task, more ecologically minded experts were contacted and incorporated to the co-operative job to 2009. Representative and external experts were requested to supply data on the two main links between grazing and biodiversity (vegetation succession and target vegetation types and species) in order to test whether a general pattern may arise over a global range of Mediterranean landscapes. They contributed with expert knowledge, personal communications or references dealing with the topic in question, within their respective systems.

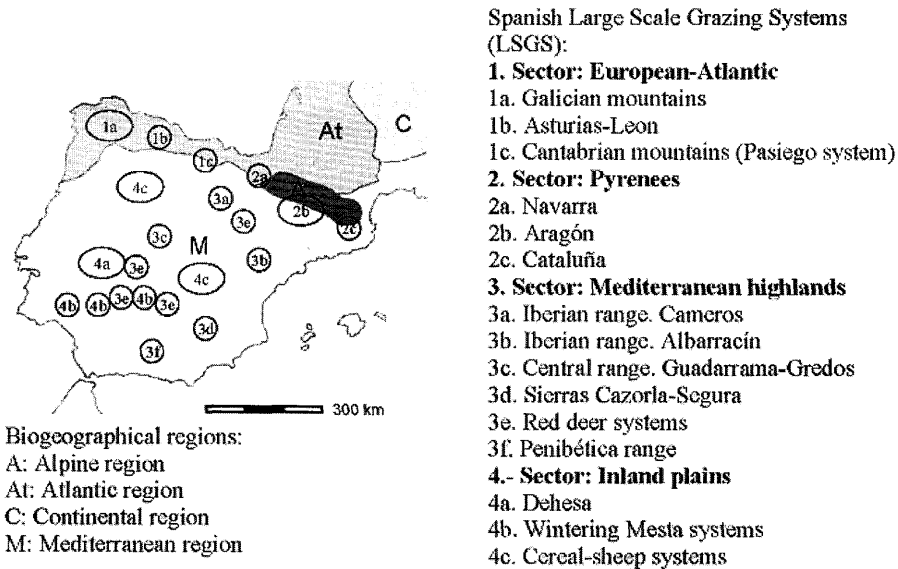
The methodological starting point for the investigation took the form of a particular request to external collaborative experts for information of LSGS on which relevant data and literature on the link between land use (or the absence of it) and species richness can be provided. While the general information provided for the individual profiles of Presentation section was rather homogeneous, this more specific subject required an assessment of the quality of information returned, further contacts with particular experts and a review of available literature. At the end, this overview informed further selection of particular case-study areas along a wide range of biogeographical sectors. The trend towards large-scale abandonment of LSGS in Spain, Italy and Greece is widespread and its effects on other ecological functions (i.e., climate change, soil and water quality, erosion) are barely addressed (Cernusca *et al.*, 1996; Vicente-Serrano *et al.*, 2004). However, the survey presented may provide a general pattern of land use and vegetation changes currently operating and their effect on species richness. The survey was carried out under the assumption that Mediterranean species include both grazing-dependent species and species adapted to post-cultivation and post-grazing succession processes. If this is the case, possible implications are that varying grazing pressure can be better for biodiversity than space-homogeneous grazing but also that large-scale abandonment may decrease biodiversity if valued by species richness.

PRESENTATION OF MEDITERRANEAN LSGS

External experts were able to locate their respective LSGS in the corresponding map. Most experts indicate that the area affected by LSGS is difficult to assess because borderlines are blurred by contiguous systems and, frequently, herds/flocks are not sedentary and mobility is a common practice over different FU over the year.

Additionally, potential and actual area affected by LSGS may differ greatly. For these reasons, areas affected by LSGS are represented as hot spots in the corresponding national maps, indicating locations where LSGS is the dominant productive land use, and tentative actual areas affected by LSGS are recorded in the correspondent individual profile of LSGS. Hot spots of larger size indicate larger areas affected by LSGS.

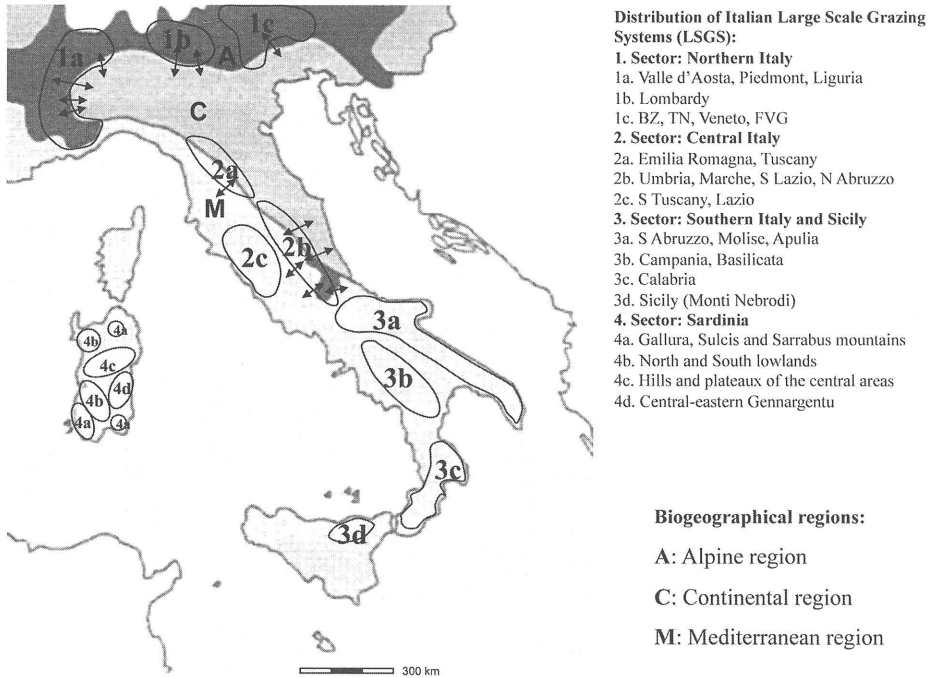
Maps 1, 2 and 3 represent the spatial distribution of the Spanish, Italian and Greek systems, respectively, in the different biogeographical regions. In the case of Greece, all Greek LSGS fall within the Mediterranean biogeographical region. In the three countries, LSGS are distributed in four geographical sectors. Corresponding main features of the respective LSGS in each country are summarized in Tables 1, 2, and 3.



MAP 1

Distribution of Spanish Large Scale Grazing Systems (LSGS) on the biogeographical regions of the Iberian Peninsula.

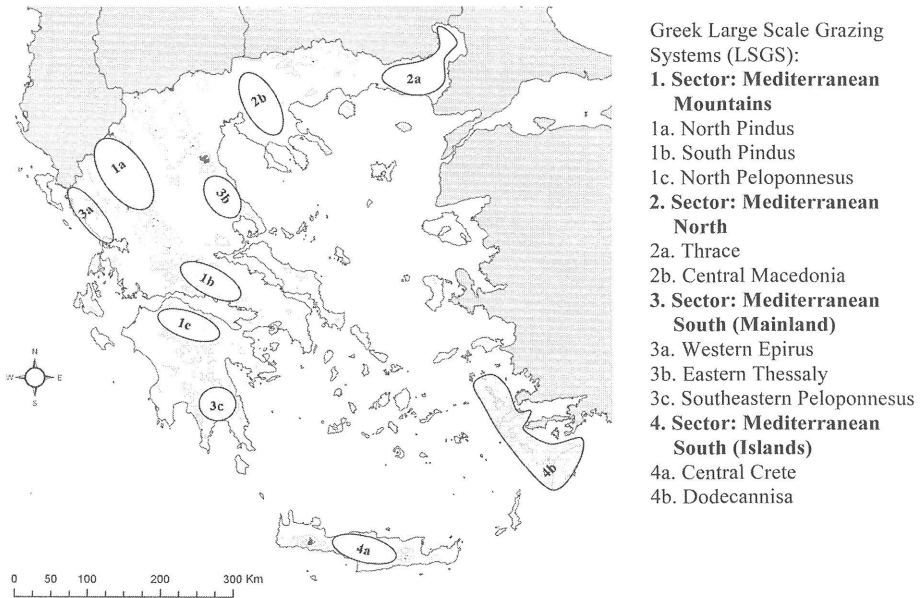
Distribución de los sistemas pastorales españoles en la Península Ibérica.



MAP 2

Distribution of Italian Large Scale Grazing Systems (LSGS) on biogeographical regions of the Tyrrhenian islands and Italian Peninsula.

Distribución de los sistemas pastorales en Italia.



MAP 3

Distribution of Greek Large Scale Grazing Systems (LSGS) on the Mediterranean biogeographical region of the Greek peninsula.

Distribución de los sistemas pastorales griegos en la regiones mediterráneas de la Península Griega.

Individual profiles of Spanish LSGS

Three European biogeographical regions are represented in Peninsular Spain: the Euro-Atlantic, the Alpine and the Mediterranean (Rivas-Martínez *et al.*, 2001a; EC, 2003). The Macaronesian region is present in the Canary Islands. The Euro-Atlantic region is represented on a fringe of some 700 km over the Galician and Cantabrian mountains facing the Atlantic. The Alpine region is present only in the upland of the Pyrenees, one mountain range stretching over some 400 km, over the Spanish-French's border. The Mediterranean region is dominant (more than 80% of the national area), with scattered inland sierras and plains. Rainfall broadly decreases in the Iberian Peninsula along the N-S and W-E axes and the mean annual temperatures broadly increase over the N-S axis. Differential spots are related to the altitude and the proximity of the seashore. Spain has a strong tradition of flock mobility, with displacements up to 700 km (transhumance). Sheep flocks moved along drove corridors (*cañadas*) between summer pastures in the N and winter pastures in the S, regulated by the old Mesta system (Klein, 1920; Martín and Sánchez, 1996; Rodríguez, 2001). Nowadays, only a small number of

flocks are displaced, mainly by lorries or trains (Elías *et al.*, 1995), and most herds/flocks are sedentary or practicing shorter displacements (some 100-150 km) between nearby grazing units (trasterminance) or vertical mobility in the mountains. The diversity of environments, indigenous livestock breeds, and regional livestock products is probably the highest in the EU (Montserrat, 1996; Sierra, 1996; Canut and Wiesenthal, 2002; Sánchez, 2002; Esteban, 2003; Martín, 2006). Out of the 218 habitat types of European interest recorded in the EU habitat Directive, Spain harbours 116 (Bartolomé *et al.*, 2005).

Two reviews of biodiversity/natural values of main Spanish pasture ecosystems have been published (Ferrer *et al.*, 2001; de Luis, 2004), as well as one special issue by the Spanish Grassland Society (SEEP, 2001). In more restricted geographical areas, it is accepted the presence of some 1500 endemic plant species, some 500 shared with North Africa. Some of these species are linked to areas with dominant pasture ecosystems (Ríos, 1991; Carrasco *et al.*, 1991; Alegre *et al.*, 1991; Cabello *et al.*, 1991; Ceballos *et al.*, 1997; Díaz *et al.*, 1999; Gómez-García and Montserrat, 1998; Ríos *et al.*, 1999; Hernández *et al.*, 2001; Vigo and Carreras, 2002). More examples of the relationship between vegetation diversity and pasture management can be found in Gómez Campo (2002); Fillat (2002), Rivas-Martínez *et al.* (2002) and San Miguel (2003). Spanish LSGS on this research will not include pastoral systems of the Canary and Balearic Islands. It should be taken into account, however, the large presence of forage endemic species in the Canary Islands and particular goat grazing systems (Santos, 1995; Jiménez, 1995; Gómez Campo *et al.*, 1996). The LSGS of the Balearic Islands represent many cultural traditions (cheese making) and environmental values (Morey, 1987; Lucas, 2002).

The European-Atlantic sector

In this sector (Cantabrian Mountains and Galician range), maritime air and frequent mists provide the necessary humidity to pastures surrounded by woodland. Open clearings in the uplands provide summer grazing lands (*brañas*) with its corresponding herders' hut (*cabañas*). Better accessible midland meadows provide grazing grounds alternating with forage conserves (hay and silage). Nowadays, large tracts of grazing grounds are abandoned with widespread invasion of *Erica cinerea*, *Calluna vulgaris* and *Ulex europaeus* (siliceous substrate of Galicia) and also *Erica vagans* (heath), *Erica arborea*, *Ulex gallii*, *U. minor* (gorse) and *Pteridium aquilinum* (bracken). In the case of Galicia, shrubby invaders may cover some 35% of forest areas. Warmer and lower slopes, especially in Galicia and Asturias, have been reforested with pine (*Pinus radiata*) and eucalyptus (*Eucalyptus globulus*). The Cantabrian Mountains act as a filter for the moist sea air, with frequent mists on the north-facing slopes. Hedges with remnants of climax oak (*Quercus robur*) and ash (*Fraxinus excelsior*) are common. The cloudy

slopes have dense beech forests (*Fagus sylvatica*). Over 1500 m, beech forest almost disappears given way to summer grazing grounds dominated by heath lands (*E. cinerea*), gorse (*U. gallii*) and holly (*Ilex aquifolium*). Livestock farmers make grazing grounds by controlled burning and spreading manure and moving animals from huts to huts like in the Pasiego system of Cantabria. In the dry south-facing slopes other shrubby species appears like *Genista obtusiramea* and *Cytisus oromediterraneus*, typical of the Spanish *piornales*.

Main forest vegetation types in this sector were recorded by Díaz González and Fernández Prieto (1994): mesophytic basiphilous beech forests (*Carici sylvaticae-Fagetum*); mixed forests (*Corylo-Fraxinetum cantabricum*); oak forests of *Quercus robur* (*Blechno-Quercetum roboris*); oak forests of *Quercus petraea* and *Quercus pyrenaica* (*Linario triornithophorae-Quercetum petraeae*); mesophytic acidophilous beech forests (*Blechno-Fagetum sylvaticae*); birch forests of *Betula celtiberica* (*Luzulo-Betuletum celtibericae*); riverine alder woodland (*Hyperico androsaemi-Alnetum glutinosae*); xerophilous and basiphilous beech forests (*Epipactido helleborines-Fagetum*), and evergreen holm oak forests (*Cephalanthero-Quercetum rotundifoliae*).

In this sector, three main LSGS are depicted in the Spanish map. In the Galician mountains and hills (**1a**), woodland and shrublands take up near 60% of the regional area (some 30000 km²), but the traditional exploitation of forest land, including grazing by indigenous breeds, has declined over the last 30 years. Currently, only some 5000 km² are considered under traditional use. Shrubby overgrowth and increase of undercover biomass are contributing to wildfire and subsequent environmental problems (Silva-Pando *et al.*, 2002). In fact, Galicia is the Spanish region with a higher incidence of fires, even more than Mediterranean territories (Moreno *et al.*, 1998; Vázquez *et al.*, 2002; Martínez *et al.*, 2009), a trend related to the maintenance of traditional management promoting vegetation control and openings for grasslands. Shrub clearing by mechanical and controlled burning and subsequent mixed grazing are common management practices contributing to the presence of some endemic species (Izco and Sánchez, 1995). The presence of mixed grazing is required to maintain the herbaceous communities of *Agrostis-Festuca* and avoid secondary succession towards shrubby communities dominated by *Calluna vulgaris* and *Ulex gallii*. This latter is better controlled by goats' grazing, while sheep fed on sproutings of *Calluna* and *Genista florida*. After small ruminants, the presence of indigenous cattle (Rubia Gallega breed) may check the turfs' spreading of *Nardus stricta*, which is rejected by sheep (Olivan and Osoro, 1998; Osoro *et al.*, 2000). Large areas under traditional use have reverted to woodland forest or reforested with eucalyptus and pines, and livestock production is progressively concentrated on intensive or semi-intensive dairy cattle with very limited use of woodland pastures.

TABLE 1
Main Spanish LSGS by biogeographical region.

Características de los principales sistemas pastorales españoles según regiones biogeográficas.

Biogeographical region and code	^a Regional location	^b Main production objectives	^c Presence of indigenous breeds	^d Actual area (km ²)	^e Main vegetation types
1. Euro-Atlantic					
1a	Galicia	MC, DS	C, S	5000	9230
1b	Asturias-León	MC, DS, G	C, S, G, H	6000	9230, 9120, 9150, 9240, 4060
1c	Cantabria	MC, DC, DS, G	C, S, G	1000	9230, 9120, 9240, 9340
2. Pyrenees (Mediterranean-Alpine)					
2a	Navarra-Basque country	MC, DC, DS	C, S	2000	9160, 9120, 9130, 9150, 9240
2b	Aragón	MC, DC, MS, G	C, S, G	6000	9340, 9240, 9530
2c	Cataluña	MC, DC, DS	C, S	2000	9240, 9340, 9530, 9120
3. Mediterranean highlands					
3a	CL-La Rioja	MC, MS	C, S, G	2000	9230, 9240, 9120, 9340
3b	CLM-Aragón	MC, MS, G	C, S, G	8000	9560, 9230, 9240, 9340
3c	CL-Madrid	MC, MS, G	C, S, G	15000	9340, 9230, 4090, 91B0
3d	Andalucía-Murcia-CLM	MS, G	S, G	2000	9340, 9240
3e	Andalucía-CLM	BG	RD	10000	As in 3a, 3d, 4a, and 4b
3f	Andalucía	MC, G	C, G	5000	9340, 4090, 6160, 9230, 9240
4. Mediterranean plains					
4a	Extremadura-Andalucía	MC, MS, IP	C, S, IP	40000	9330, 9340, 9230
4b	Extremadura, Andalucía, CLM	MC, MS, IP	C, S, IP	6800	9330, 9340, 9230
4c	CL-CLM	DS, G	S, G	70000	9340, 9240

^a Main geographical territories of presence. CL=Castilla and León; CLM=Castilla-La Mancha.

^b MC: Meat cattle; DC: Dairy Cattle; DS: Dairy Sheep; MS: Meat Sheep; G: Goats; BG: Big Game; IP: Iberian Pig.

^c Presence of indigenous breeds of Cattle (C), Sheep (S), Goats (G), Red Deer (RD) and Iberian pig (IP).

^d Area is approximate; potential area can be larger.

^e Main types of natural vegetation referred to habitat codes of the Directive 92/43 (EC, 2003).

Asturias, and the North of León, is the nucleus of the Cantabrian Mountains, with some 6000 km² under LSGS (**1b** in the Spanish map). Some successional vegetation trajectories are shared with the previous type. From a management point of view, two main sub-types can be differentiated. The first is a meat cattle (Casina breed) system including some free-roaming horses (Asturcones) with only occasional care of livestock, and the second, a mixed cattle-sheep system, including some goats, for the production of indigenous cheeses (Cabrales, Gamoneu), with more intensive care of herds/flocks (Mayor, 2002). This LSGS includes some protected areas such as Picos de Europa National Park and some Natural Parks (Somiedo, Riedes or Riaño). In this LSGS the abandonment threat is also present. In the municipality councils of Onís and Cangas de Onís (some 30000 ha), in Asturias, only eight livestock farmers bring currently their animals to the upland *brañas* of Picos de Europa for summer grazing. This distinctive management is jeopardizing the traditional production of the three-milk' cheese (Gamoneu de Puerto). The upland *brañas* are used sequentially for indigenous cattle, sheep and goats, and Asturcones horses; the latter cleaning mature herbage refuses. Intensive and semi-intensive dairy cattle are abundant in farms near the coast with progressively higher use of forage conserves and concentrate feeds.

In the Eastern part of the Cantabrian Mountains, two additional LSGS sub-types are differentiated (**1c**): the trasterminance system and the Pasiego system. In the first (some 3000 km²), summer grazing is remote from farm holdings, with lowland grazing in spring and autumn under shared management of private land (*derrotas*). Herders meet the animals only occasionally. Indigenous cattle (Tudanca) are on retreat and maintained on specific mountain valleys (Cabuérniga), while intensive dairy cattle near the coast is dominant. The most striking feature of the Pasiego system is the vertical mobility of animals and herders from hut to hut of progressively higher altitude. The Pasiego system is currently a mountain grazing system mainly orientated to selling first calving American Holstein heifers to more intensive dairy herds, near the coast, where these heifers are greatly appreciated. Some indigenous dairy sheep (Lacha breed) and goats are also present in the Eastern Cantabrian mountains for the production of indigenous cheeses such as Pasiego (cattle milk) or Picón (three milks' cheese in the Liébana area). Common species in the mountain pastures are *Festuca nigrescens*, *Agrostis capillaris*, *Nardus stricta* and *Carex* spp. Busqué *et al.* (2003) stressed the importance of mixed grazing as cattle may check the spreading of *Nardus stricta* while sheep may control the invader *Euphorbia polygalifolia*.

The Pyrenean sector

In this Mediterranean/Alpine sector, drained by the Ebro River, livestock farming is structured by moving animals from the lowland to the upland Pyrenean grazing grounds

during the summer season (trasterminance). In these seasonal movements, grazing animals (mainly sheep) may use communal grazing grounds (*boalares*) and rented land in the midland villages (Montserrat and Fillat, 2004). For most sedentary animals in the central part of the Pyrenees (cattle herds), hay-making is common in the valleys and forage conserves stored in farm-building (*bordas*), where animals are managed during the non-grazing season. Manure is further spread in the meadows at the beginning of the next springtime.

The dominant trees are semideciduous oaks (*Quercus faginea* and *Q. pubescens*). Box (*Buxus sempervirens*) and holm oaks (*Q. ilex*) are present on the driest slopes. Upland forests are dominated by *Pinus uncinata* while, *Fagus sylvatica* is also present in humid valleys. Main forest vegetation types in this sector were recorded by Mayor (2002): mixed eutrophic forests (*Fraxino-Carpinion*); eutrophic beech forests (*Scillo-Fagetum*); meso-xerophilous calcareous beech forests (*Buxo-Fagetum*); riverine alder woodland (*Alno-Padion*); forests of *Pinus sylvestris* (*Hylocomio-Pinetum*); forests of *Abies alba* (*Galio-Abietetum*); forests of *Pinus uncinata* (*Arctostaphylo-Pinetum uncinatae* and *Saxifrago-Rhododendretum pinetosum*); and forests of *Abies alba* with *Rhododendron ferrugineum* (*Saxifrago-Rhododendretum abietosum*).

Three main LSGS are depicted in this sector in the Spanish map. In Navarre (**2a**), the dominant grazing animal is the Lacha sheep breed (milk-oriented). Both sequential and mixed grazing (cattle, sheep and horses) are practiced. Most indigenous cattle grazing are sedentary in the Pyrenean valleys and sheep flocks practice trasterminance between the lowland pastures of the Bardenas in winter and upland pastures during the summer. Meat-oriented sheep (Rasa Aragonesa) is common in the Salazar valley and milk-oriented sheep (Lacha breed) in the Roncal valley, where the Roncal cheese is produced. Livestock farmers' associations within valleys deal with grazing management. Montane habitats include altimontane (1000-1500 m), subalpine (1500-2000 m), and a small proportion on the alpine belt (more than 2000 m). Mountain landscapes include a mosaic of pasture and forests with *Fagus sylvatica* in the montane belt and *Pinus uncinata* in the subalpine belt. Grazing helps to maintain open landscapes with severe risk of ecotones being invaded by shrubby species in abandoned areas. Under deficient grazing planning, *Nardus stricta* and *Carex* spp. are invaders.

In the Central part of the Pyrenees, LSGS (**2b**) take up a larger area (some 6000 km²) than in Navarre (some 1000 km²). The communal grazing systems persist in the Pyrenean valleys of Aragón since the Middle Age. The traditional trasterminance to winter lowland pastures is in retreat due to agriculture intensification in the Ebro valley. Great parts of the higher slopes, that were fields and pastures long time ago, are covered now, after abandonment, by shrublands and mixed or coniferous forests (Vicente-Serrano *et al.*, 2004). A trend to increase cattle grazing and decrease of sheep grazing is apparent.

While livestock in upland pastures for some four months, forage conserves (mainly hay making) are made from natural pastures of *Arrenatherethea* and *Festuco-Brometea* for winter indoor feeding in the lowland farms. During early spring and autumn, the herds use private or communal pastures near the villages (*boalares*). The area included some important protected areas such as Ordesa National Park, where 55 plant taxa are endemic, of which 41 are linked to pastures of *Mesobromion erecti*, *Nardion strictae* and *Festucion gautieri* in the subalpine belt (Aldeazabal *et al.*, 1992). Natural resources and indigenous livestock breeds are the source of indigenous products such Ternasco de Aragón from Rasa Aragonesa meat-oriented sheep and some local cheeses from cow's milk produced in the Ansó-Hecho and Benasque valleys (Sierra, 2000).

In the Eastern part of the Pyrenees (2c), meat cattle are dominant with farmers alternating Mediterranean cultivation of crops and forage with trasterminance of cattle to the uplands. The region also includes some important protected areas such as Aigüestortes i Estany de Sant Maurici National Park in Catalonia, with some 2000 km² under LSGS. Typical biodiversity of Pyrenean valleys (Arán, Boi) is present with strong tradition of mountain grazing (Poyatos *et al.*, 2003) and artisan cheese-making mainly by cow and goats' milk (Alt Urgel and Cerdanya, Osona, Musa, La Garrotxa and Sierra del Montsec). The indigenous meat-oriented Bruna cattle breed, with some 30000 animals censused, is the source of the appreciated meat controlled by a regulatory council.

The Inland Sierras sector

In the Spanish inland, two main plains (N and S Castilian Plains) are surrounded by several mountain ranges: the Iberian range (NW-SE) and the Central, Montes de Toledo, and Sierra Morena ranges (E-W). In the south, the Penibética range drains to the Guadalquivir valley and to the Mediterranean Sea. These mountainous and inland areas are the less developed and under-populated of Spain. In some areas of the Sierra de Albarracín and Alto Tajo, population density can be even less than five inhabitants per km². Family farms alternate with large farms of absentee owners and patches of communal land managed by village councils. Non-arable land is dominant with some cultivation in the lowland valleys and better quality soils. Patches of Mediterranean forest, shrublands and natural pastures are dominant, with the latter decreasing as abandonment of many of these areas caused forest and shrub encroachment. Controlled and uncontrolled forest fires and soil erosion are causes of concern that can be related to grazing use. In the past, occasional overgrazing in some areas could be a cause of concern. Nowadays, many villages are under-populated for an aging population, or even totally abandoned, deriving under use, especially of those far-reaching grazing grounds. Uncontrolled forest fires on these areas are increasing with contrasted arguments over their main causes. The abandonment of traditional grazing practices in these areas, with

corresponding shrubby overgrown, should be a main cause of concern (Martínez *et al.*, 2009).

Many small LSGS in extension, but of great importance for biodiversity, are operating in the Spanish Sierras. Some of these systems may have certain correspondence with others located in Central Italy or Greece, although inland continentality makes a difference. In the Spanish LSGS map, we have depicted six of them (**3a** to **3f**), without considering a closed list.

In the Iberian range (**3a**, **3b**) some important inland Sierras are Cameros, Gúdar-Valdelinares, Albarracín and Serranía de Cuenca. LSGS take up more than 10000 km² in the provinces of Logroño, Soria, Teruel, Cuenca, Guadalajara and Castellón. Some grazing grounds were important summer pastures for the old Mesta system (Cameros and Albarracín). Forest clearing was an important activity in managing landscapes and allowing summer grazing of the Mesta flocks. Nowadays, large tracts of the inland Sierras are abandoned or forested with natural or reforested pines' populations (*Pinus sylvestris*, *P. pinaster*, *P. nigra* and *P. halepensis* are dominant). In the submontane level, oak (*Quercus rotundifolia*, *Q. pyrenaica* and to a lesser extent *Q. faginea*) and *Juniperus thurifera* forests and woodlands are present with clearings ecotones in danger of being overgrown by shrubby invaders if grazing is abandoned. Pastoral resources include natural grassland, shrubby vegetation communities, and agricultural residues (cereal stubbles) in small patches of arable land more near the valleys. Encroachment by *Genista*, *Calluna* and *Crataegus* spp. is common in highland pastures under risk of abandonment. Cattle grazing for Serrana Pinariega (Camerana) and crosses with foreign breeds (Charolais and Limousine) are dominant in the Northern Iberian range, with some indigenous sheep flocks (Castellana, Ojalada and Merino breeds) practicing trasterminance between the arable land fields and upland pastures. Indigenous cattle (Camerana) are almost unherded, with low gregarious activity and well adapted to harsh mountain environment. It hampers the spreading of young sprouts of *Calluna* and favours the turfs spreading of *Festuca* aggr. *indigesta*. This grass contributes to cattle feeding and even may limit the effect of avalanches during winter (Monserrat, 2001). Rough grazing, by including horses and goats, is also needed to clean mature herbage, controlling shrubs and favouring herbaceous re-growth. Sheep and goat farmers may have two sheepfolds, one near the villages where flocks graze on agricultural residues of private land during summer and autumn and other in the communal upland pastures used mainly in springtime. In the Southern Iberian range, indigenous sheep (Alcarreña, Manchega, Merina, Ojalada) and goat (Blanca Celtibérica) farming is dominant (García Dory *et al.*, 1990); a large number of livestock farmers being landless pastoralists, who rent agricultural residues to arable farmers under a customary use-right. A few of them, mainly from Cameros and Albarracín, still practice the old long-distance (some 400-500

km) transhumance to winter pastures in more southern areas of Jaén and Ciudad Real. Nowadays displacement of flocks is by special trains or trucks (Elías *et al.*, 1995).

The Central range stretches E-W over the Sierras of Ayllón, Guadarrama, Gredos, Béjar, Gata, and Serra da Estrela, the latter in Portugal. In Spain, areas under LSGS (3c in the Spanish map) take up some 15000 km² and some 300000 Livestock Units (LU) of mainly meat-oriented indigenous cattle (Avileña, Morucha and Serrana Negra breeds). Goat grazing is more common in shrubby-dominant plant communities of the Western Central range for the provision of highly appreciated kids' meat and local cheeses (Acehuche, Gata-Hurdes, and Valle del Tiétar). Livestock grazing extends from spring to autumn within management units of lowland and upland pastures. Winter-feeding is usually carried out in-door with forage conserves and concentrate supplementation, especially when foreign breeds (Charolais, Limousine) are used as single or crosses. A progressively small number of Avileña herds still practice the trasterminance to winter pastures in the *dehesas* of nearby Extremadura (Cáceres province). LSGS are essential for maintaining open landscape and fire prevention. Under frequent abandonment, upland pastures are encroached by *Cytisus oromediterraneus* and *Genista* spp., with corresponding decrease of forage value and species richness. Rangeland utilization is heterogeneous and occasional overgrazing may occur in pastures near the villages (Campos Palacín and Martínez-Jaúregui, 2004; González and San Miguel, 2004).

Main vegetation types of the Guadarrama sub-sector at the association level were reported by Izco (1983) and Rivas Martínez *et al.* (1999): forests of *Quercus pyrenaica* (*Luzulo-Quercetum pyrenaicae*); forests of *Fraxinus angustifolia* (*Quercus pyrenaicae-Fraxinetum angustifoliae*); forests of *Betula celtiberica* (*Melico-Betuletum celtibericae*); pine forests (*Avenello-Pinetum sylvestris*); subalpine scrub of *Cytisus oromediterraneus* (*Senecioni-Cytisetum oromediterranei*); mountain pastures above the timberline (*Hieracio-Festucetum curvifoliae*); scrub of *Santolina rosmarinifolia* (*Artemisio-Santolinetum rosmarinifoliae*); scrub of *Cistus laurifolius* (*Santolino-Cistetum laurifolii*); scrub of *Adenocarpus hispanicus* (*Genisto-Adenocarpetum hispanici*); and scrub of *Cytisus oromediterraneus* with *Genista cinerea* (*Pteridio-Genistetum cinerascens*).

In the Bética range (South East of Spain), LSGS comprise some 2000 km² in the provinces of Albacete (Sierra de Segura-Alcaraz), Jaén (Sierra de Cazorla and Sierra Mágina) and minor parts of Murcia and Granada (3d). Some 160000 sheep are present in the Segura-Alcaraz system. Several reserves are located in this range: Natural Parks of Sierra Mágina, Sierra de Cazorla and Calares del Mundo y La Sima. Dominant indigenous breeds are Segureña (meat-oriented sheep) and Serrana (white or black) goat. A small number of indigenous cattle herds are also present (Pajuna). Shepherd run the flocks through communal pastures and besides rent some private forestland. Flocks graze freely part of the time and shepherds take care of the flocks in turns of some three

months, and meet together for changing to a new grazing area. Vertical trasterminance is common from lowland valleys (spring and autumn) to upland pastures (some 1500-2000 m) in summer. Some flocks migrate to nearby Sierra Morena during winter. In contiguous areas with more arable land, semi-intensive cereal-sheep systems are found, flocks using agricultural residues (cereal stubbles and fallow) during summer and autumn and increasing the reliance on concentrate indoor feeding (Correal and Sotomayor, 1998). Vegetation strata and main representative species from valleys to upland pastures include:

Riverine vegetation is present at altitudes below 800 m: *Salix fragilis*, *S. atrocinerea*, *Populus nigra*, *Robus ulmifolius*, *Scirpus holoschoenus*, *Lolium perenne* and *Festuca arundinacea*.

From 800 to 1500 m: evergreen holm oak (*Quercus rotundifolia*), pine (*Pinus nigra* subsp. *salzmannii*, *P. pinaster*) forest, *Cytisus reverchonii*, *Pistacia terebinthus*, *Lavandula latifolia*, *Rosmarinus officinalis*, and herbaceous *Brachypodium retusum* and *B. phoenicoides*.

From 1500 to 1700 m: open forest (*adehesados*) of deciduous *Quercus faginea* and *Q. pyrenaica* with *Crataegus monogyna*, *C. laciniata* and herbaceous *Poa bulbosa*, *Festuca* subsp., *Agrostis* subsp., *Trifolium subterraneum*, *Medicago minima* and *Astragalus sesameus*.

Above 1700 m: cushion scrub, pastures and open pine forest of *Pinus nigra* subsp. *salzmannii* with *Vella spinosa*, *Erinacea anthyllis*, *Hormathophylla spinosa*, *Festuca hystrix* and *F. hackelii*.

Lack of grazing planning may induce overgrazing in some lowland areas with abandonment of far-reaching grazing grounds. Abandonment is related to increasing vegetation cover of some hemipterophytic species, lowering cover of herbaceous annuals (mainly *Compositae*) and dominance of perennial grasses such as *Brachypodium retusum* (Fernández Rebollo *et al.*, 2001).

The red deer system (**3e**) occupies large areas (some 10000 km²) of dense Mediterranean vegetation mainly along the Iberian System, Montes de Toledo and Sierra Morena ranges. Provinces with higher number of big game trophies are Jaén (Sierras de Andújar and Cazorla), Córdoba (Sierras de Cardena and Montoro), Ciudad Real (Sierra Madrona), Toledo (Montes de Toledo), and minor areas in the provinces of Badajoz, Cáceres, Teruel and Soria. Red deer systems operate in areas with a previous history of sheep and goat grazing, where abandonment has given way to a dense undercover of shrubby vegetation. This vegetation type provides hidden cover, but animals require also some interspersed patches of open herbaceous clearings for feeding and during the mating season, usually in the lowland valleys. Proper interspersed of both habitat types provides the higher habitat suitability index (Caballero, 1985; Montoya, 2001). As

shrubby propagules abound, herbaceous clearings are to be maintained by mechanical and burning controls (Bernal *et al.*, 2001) or occasional plugging and sowing of complementary forages such as mixtures of green cereals and vetches. Most of the red deer farms are privately owned and fenced. Others hunting allotments are under control of village councils or protected areas such as Cabañeros (Ciudad Real-Toledo) and Monfragüe (Cáceres) National Parks. Mean advisable stocking is some 4-5 ha per animal, but some overstocking (up to only 1-2 ha per animal) or too small fenced areas are common concerns in privately owned farms (Caballero, 1985; Cano and Ruiz, 1997; Fernández-Olalla *et al.*, 2006).

The Penibética range (3f) stretches E-W over some 300 km from the arid Mediterranean coast (Sierras de Gata, Gador and Filabres in Almería) to the western and more humid Sierras of Grazalema and Las Nieves, more near the Atlantic coast in the province of Cádiz. It encompasses different bioclimatic and edaphical conditions with thermo-Mediterranean in the E and oro- and supra-Mediterranean in the W and at higher altitudes. In the middle, the Sierra Nevada range, in the province of Granada, has the highest peak in the Iberian Peninsula (Mulhacén, 3478 m).

In the arid part (some 200 mm of mean annual rainfall), the steppic vegetation is dominated by *Anthyllis cytisoides* (albaida), *Stipa tenacissima* (espartales), *Thymus baeticus* (tomillares) and *Chamaerops humilis* (palmito) in vegetation communities that can reach up to 3-4 units in the Shannon index (Boza, 2003). In the Sierra de los Filabres, Peñas *et al.* (2003) found 15 communities of natural grasslands, of which 10 were clustered in the phytosociological class of *Lygeo-Stipetea*, three in the *Festuco-Ononidetea*, one in *Nardetea* and one in *Poetea bulbosae*. In the Sierra de Gádor, *Lygeo-Stipetea* is also well represented by perennial graminoid pastures and scrubs with grasses like *Brachypodium retusum*, *Lygeum spartum*, *Stipa tenacissima*, *Festuca scariosa* (lastón) and *Hyparrhenia hirta* (Giménez Luque *et al.*, 2003). In the most humid part to the W (up to some 2000 mm of rainfall in particular niches), forests of *Quercus suber*, *Q. faginea* and *Q. canariensis* are found in the Natural Park of the Alcornocales and endemic forests of *Abies pinsapo* in the Sierras de Grazalema and Las Nieves. Private and public land is interspersed with dominance of indigenous sheep (Segureña) and goats (Murciano-Granadina and Malagueña) in the E and some indigenous cattle to the W (Pajuna). In the Natural Park of Cabo de Gata-Níjar, Pueyo *et al.* (2003) showed dominance of *Stipa tenacissima* as an indicator of overgrazing by sheep and goats. Medium grazing intensity showed highest diversity (2.78 in the Shannon index) and evenness (0.64 in the *J'* index of Pielou) due to higher presence of annuals and shrubs. Vegetation cover and rainfall indicators have been used to estimate carrying capacity in a wide range of pastures in this area (Passera *et al.*, 2001).

The plains sector

Three main LSGS are depicted in the Spanish map for this sector: the *dehesa* (4a), the old wintering grazing grounds of the Mesta system (4b), and the cereal-sheep system (4c).

The *dehesa* system (4a) occupies large tracts of the Western and SW part of the Iberian Peninsula making a continuum along the Spanish-Portuguese border in the *montado* system. In Spain, it takes up some 40000 km² in the region of Extremadura (provinces of Cáceres and Badajoz) the North parts of Huelva, Sevilla, Córdoba and Jaén, the Southern parts of Ciudad Real and Salamanca and the western part of Toledo.

Open forest of evergreen holm oak (*Quercus rotundifolia*) and other oak species with undercover herbaceous vegetation is the dominant landscape. Due to the poor quality of siliceous soils, cultivation is restricted to some 1/5 of the area under a rotational system. This 20-25% of the area is dedicated mainly to grain cereals, green cereals or green cereal-vetch mixtures in support of animal feeding. In the case of grain cereals, the cereal stubble is grazed over the summer (if Merino or Entrefino sheep exists). More and more concentrate feeding is provided over the summer drought season. This practice is more common if meat cattle (indigenous Retinta, Morucha and Avileña breeds) and Iberian pig are the production objectives and grain cereals are not planted. The occasional cultivation has also the objective of controlling the shrubby invaders. Mixed grazing is common, although an increasing number of farms specialize on single meat cattle, Iberian pig or bullfight rising. The latter operation takes up some 3000 km², mainly in the provinces of Cádiz, Jaén, Córdoba, Badajoz, Cáceres and Salamanca.

Pig grazing of pasture and acorn is extended from October to next January (*montanera*) and only herbaceous feeding over the spring. Seed maturation and reproduction of annual legumes such as *Trifolium subterraneum* is favoured by a livestock-resting period in late spring (Garzón-Heydt, 2003). Complementary feeding is provided over the rest of the year, especially during the dry summer season. Pig grazing of herbage and acorn can be extended if a mixture of *Quercus* spp. is present in the *dehesa*. Acorn maturation from early- to late-maturing species is as follows: *Q. faginea* subsp. *broteroi* (Lusitanian oak), *Q. pyrenaica* (Iberian oak), *Q. rotundifolia* (evergreen oak), and *Q. suber* (cork oak). Mean production of acorn in evergreen oak is some 700 kg/ha. Lusitanian oak and Iberian oak are companions of evergreen oak in the *dehesas* located at higher altitudes. Mean stocking is some one pig per 2 ha at the beginning of the finishing period in the *montanera* (40-50 kg of live weight) and one pig per 3 ha at the end (100-120 kg LW). Young pigs from the spring breeding season reared in pastures (higher protein content) with their mothers and finished in the next period of *montanera*.

Pastoral vegetation communities of the *dehesa* system are included in the EU Habitat Directive and grazing management greatly affects vegetation changes (see Successional

Trajectories section). Syntheses of soils, vegetation types and species composition of typical *dehesas* have been published by Marañón (1985, 1986), Montoya *et al.* (1988), Joffre *et al.* (1988), San Miguel (1994), Gómez Gutiérrez and Pérez Fernández (1996), and Díaz *et al.* (1997). A current concern that may hamper the long-term sustainability of the *dehesa* system deals with the regeneration of trees, clearly threatened in absence of an adequate forestry management due to the scarcity of habitat available both for natural seed dispersers and seedling survival, and damage by herbivores to tree seedlings and juveniles (Pulido and Díaz, 2002; Llorente, 2004). Summaries of grazing management techniques to improve productivity and environmental values are available (Crespo, 1997; Olea and San Miguel, 2006).

Most *dehesas* are private landholdings with fences. Livestock complete the annual cycle without migration. Some *dehesas* may receive external animals for late autumn-early spring and act as wintering pastures like in old times. The extensive livestock operation is congenial with wildlife with some wintering birds such as crane (*Grus grus*) feeding on acorn (Díaz *et al.*, 1996).

The old wintering Mesta system (**4b**) occupies a W-E corridor along the Sierra Morena range, under continental Mediterranean climate. Three main inland plains (500-700 m) are representative of this LSGS: the Alcudia valley (S of Ciudad Real), which extent over some 1300 km²; Los Pedroches (N of Córdoba), which extent over some 2500 km²; and La Serena (S of Badajoz), which occupies some 3000 km². These were wintering grazing grounds of Mesta sheep flocks droving along the *cañadas* (some 600-700 km) from summer grazing pastures in the North of Spain (Mestas of León, Soria and Segovia). Nowadays, most sheep flocks are sedentary and grazing in private fenced farms. Forests of *Quercus rotundifolia* (*Quercetea ilicis*), with some *Q. faginea*, *Q. suber* and *Q. pyrenaica*, the latter at higher altitude, are the natural vegetation. Annual grassland of the *Tuberarion* and *Thero-Brachypodion* alliances are common in less evolved soils, while *majadales* of *Poa bulbosa* and *Trifolium subterraneum* appears under well-planned sheep grazing influence. Merino sheep flocks are dominant in Alcudia and La Serena and mixed Merino, Retinto cattle and Iberian pig in Los Pedroches. In the latter, the *dehesa* landscape is dominant allowing Iberian pig husbandry, processing and marketing. A phytosociological classification of pastures related to livestock grazing species is provided by Cano *et al.*, (2003).

The cereal-sheep system (**4c**) occupies the two largest inland plains in the Iberian Peninsula, separated by the Central mountain range. The N plain takes up most of the geographical region of Castile and León (the largest in the EU), and the S plain most of Castile-La Mancha (the third largest in the EU). The cereal-sheep extensive farming system in both regions is under change of intensification and abandonment threats, the first probably more acute in Castile and León and the second in Castile-La Mancha

(CLM). Both areas show a continental Mediterranean climate with hot and dry summers and frosty winters. Mean rainfall (mainly in spring and autumn) is higher in the N plain, under the Atlantic influence (450-550 mm in most of the area) than in the S plain (400-500 mm). In most of the Castilian plains, except in a small part of S Castilian plain more near the Mediterranean, rainfall is higher than 350 mm and the climatic climax is a Mediterranean forest of *Quercus ilex* subsp. *ballota* (= *Q. rotundifolia*) and not a true steppic vegetation (Peinado and Martínez Parras, 1987). In the Northern part of Castile and León, more near the Cantabrian Mountains, with higher altitude and rainfall, *Quercus pyrenaica* forests are dominant (see Table 4). However, secondary succession towards the climatic climax is a low timescale process limited by poor soils, reduced rainfall, and cultivation. In this arable-dominant LSGS (some 80% of Total Agricultural Land (TAL) in La Mancha), cultivation (mainly rain-fed cereals) maintain the open landscapes, and cultivation intensity and management are more determinant for natural values than vegetation types. For the purpose of this research, we will refer mainly to CLM.

Remnants of Mediterranean forest and shrub-steppic vegetation (*eriales*) still take up some 20-30% of TAL in CLM, occupying the less quality and steeply soils, which were not uprooted for cultivation. These covered landscapes do not provide suitable habitat for some target steppe birds such as Great Bustard (*Otis tarda*), which require open landscapes (Martínez, 2005). Cultivation maintains these open landscapes but high cultivation intensity, associated to “white” or bare fallow, decreases habitat suitability for steppe birds and hampers sheep farming integration by increasing disturbance, homogenization of landscapes and decreasing availability of pastoral resources. An intermediate sub climax state seems to be the more appropriate for the management of economics and natural values (see Section IV).

The South Castilian Plain, with its open and treeless landscape, is the result of two driving and frequently uncongenial forces: arable farmers and pastoralists (Caballero, 2002; Caballero *et al.*, 2004). Under the scenario of EU subsidies unlinked to production alternatives (decouplement), low-productive arable farmers may detach, increasing the hectares of uncultivated land. Under this scenario, the presence of small ruminants is of the outmost importance because they may represent the only brake towards woodland forest and maintaining open landscapes suited to steppe birds. The currently relevant question is whether small ruminant grazing should be considered negative, neutral or congenial with natural values at the landscape scale (see Section IV).

Mixed cereal and sheep farming is carried out on the same land units (*polígonos de pastos*). These sheep allotments made up of an aggregation of small parcels of up to 70 landowner cultivators. Landless pastoralists pay a per-hectare grazing fee to rent them, and manage sheep under continuous shepherding. Grazing management is under the

surveillance of Local Grazing Commissions and the village councils but, even so, lack of co-operation between arable farmers and pastoralists is a main constraint. A regulatory council is in charge of promoting the indigenous Manchego cheese (Caballero, 2003).

Individual profiles of Italian LSGS

Three biogeographical regions are represented in Italy (total area: 301338 km²): Alpine, Continental and Mediterranean (EC, 2003). The Alpine region is represented on the Alps and in the upland of Abruzzo Apennines (Gran Sasso d'Italia and Majella). The Continental region includes the plain areas of north and the central-eastern sectors. The Mediterranean region is dominant, including the rest of the Peninsula, Sicily and Sardinia (see Map 2).

As in Spain, the historical review traces the dynamic of evolution and explains the actual situation. Traditionally, sheep transhumance was structured since the Middle Age in the central and southern Apennines, with an organized pastoral society from Abruzzo to Apulia (Marino, 1988; Cazzola, 1998; Canosa, 2000). It was also practiced between the mountains and the lowlands of the old Papal State, now including large tracts of Emilia-Romagna, Marche, Umbria and Lazio regions (Boscaglia, 1920; Pullè, 1937; Quilici, 1987; Paci, 1987; Cordella and Lollini, 1988). Large movements of flocks were also practiced in Tuscany, from the Apennines to Maremma, and in Sardinia. Collective management in the Alps was present in Alto Adige and Veneto (Pastore and Fabbris, 1999; Pastore, 2002) with movement of animals from mountain pastures to the Po valley. Traditional systems represent currently a residual activity. Vertical movement of animals are still practiced in the Alps with a number of mountain farms and alpine pastures ("alpeggio", "malga" or "alpe") holding animals during the summer under a short distance vertical trasterminance. In Northern Italy some longer distance movement are still practiced by sheep farms, mainly by lorries or along some corridors between the mountain and the lowlands (Corti, 2007; Fortina, 2007). In Central and Southern Italy, the decrease of sheep number and the transformations of the traditional systems occurred in the last century, caused by the relevant changes of the economic and social conditions, strongly reduced the traditional mobility (Santilocchi and D'Ottavio, 2005). The old transhumance, to transfer the animals on foot on long distances between the mountain pastures and the lowlands along ancient drove corridors (*strade romane* or *tratturi*) disappeared. Nowadays, a vertical trasterminance is mainly performed on short distances (100-200 km), mainly by lorries, or local shorter displacements and sedentary systems are prevalent (D'Ottavio and Scotton, 2002a, b).

Italian flora includes 7634 *taxa* of which 1021 endemic (Conti *et al.*, 2005). Many of them are linked to pasture ecosystems (Arrigoni *et al.*, 1977-91; Lucchese *et al.*, 1995; Scoppola *et al.*, 2005). In Italy 127 habitats of community interest listed in the Annex 1

of the Habitat Directive (EC, 1992) are represented. Of them 31 are considered priority habitats (Petrella *et al.*, 2005). The grassland formations, connected to agronomical and pastoral uses, have been framed into different phytosociological classes: primary grasslands, largely to the *Carici rupestris-Kobresietea bellardii*, *Elyno myosuroidis-Seslerietea coeruleae* and *Nardetea strictae* (Feoli Chiappella and Poldini, 1993; Poldini and Oriolo, 1997; Sburlino *et al.*, 1999; Buffa and Sburlino, 2000; Blasi *et al.*, 2003); mesophilic and mesohygrophilous aspects of mowable meadows to the *Molinio-Arrhenateretea* (Poldini and Oriolo, 1994; Buffa *et al.*, 1997); semiarid and mesophilic aspects to the *Festuco-Brometea* (Feoli Chiappella and Poldini, 1993; Biondi *et al.*, 1995, 2005; Lucchese *et al.*, 1995; Poldini, 1995). The open perennial prairies of *Lygeo-Stipetea* class (Brullo *et al.*, 1997) and the ephemeral therophytic meadows of *Tuberarietea guttatae* class are also relevant for the Mediterranean areas. The class *Poetea bulbosae* is also particularly relevant in the siliceous areas of Sardinia (Ladero *et al.*, 1992; Farris *et al.*, 2007). According to the European CORINE land cover classification (EEA, 2003) Italian natural prairies (continuous and discontinuous) represent about 6% of the nation's area.

In Italy, four main geographical sectors were identified (Table 2): Northern Italian, Central Italian, Southern Italian and Sicilian, and Sardinian sector. The first one includes three sub-sectors: western, central and eastern. The second and the third sectors include three and four sub-sectors respectively. According to the framework profile, the main characteristics of Italian LSGS in the four geographical sectors are described.

The northern Italian sector

In Northern Italy, the LSGS are mostly located in the Alpine biogeographical region and, for the mobility of the long-distance transhumant flocks, also in the Continental one. The Alps exhibit an impressive variety of habitats and climatic conditions along relatively small spatial scales and have a long history of human presence and exploitation. The permanent grasslands cover about 17000 km² in a wide range of topographical, geological and climatic conditions. The main lithological substrata are represented by crystalline rocks in the central and western areas and by dolomite and limestone along the eastern areas. The following bioclimates of the temperate region are represented: temperate oceanic along the entire Alpine arc; temperate semi-continental, in the Alpine valleys; temperate oceanic semi-continental, in the central and eastern Pre-Alps (Blasi and Michetti, 2007). The climate, in general, is characterized by moderate or absent summer water deficit, absence of aridity, and thermic efficiency concentrated (52%) during three summer months. These conditions allow sufficient forage production of the pastures (Cavallero *et al.*, 1992; Ziliotto *et al.*, 1992) and the permanent meadows cut for hay production making (Ziliotto *et al.*, 1981; Rodaro *et al.*, 2000; Scotton *et al.*, 2000).

TABLE 2

Main Italian LSGS by biogeographical region.

Características de los principales sistemas pastorales italianos según regiones biogeográficas.

Biogeographical region and code	^a Regional / territorial location	^b Main production objectives	^c Indigenous breeds	^d Actual area (km ²)	Main types of natural vegetation (habitat codes of the Directive 92/43; EC, 2003)
1. Northern Italy (Alpine, Continental)					
1a	Valle d'Aosta, Piedmont, Liguria	MC, DC, MS, DS, G	C, S, G	8300	9110, 9120, 9130, 9150, 9180, 91B0, 91D0, 91E0, 91F0, 9210, 9220, 9260, 92A0, 9330, 9340, 9410, 9420, 9430, 9530, 9540, 9580
1b	Lombardy	MC, DC, MS, DS, G, P	C, S, G	1400	9110, 9130, 9150, 9170, 9180, 9190, 91B0, 91E0, 91F0, 9260, 92A0, 9410, 9420, 9430
1c	BZ, TN, Veneto, FVG	MC, DC, MS	C, S, G	1800	9110, 9130, 9140, 9150, 9170, 9180, 91B0, 91D0, 91E0, 91F0, 9260, 92A0, 9340, 9410, 9420, 9430
2. Central Italy (Alpine, Continental, Mediterranean)					
2a	Emilia Romagna, Tuscany	MC, DS	C, S, H	300	9110, 9150, 9180, 91E0, 91F0, 9210, 9220, 9260, 92A0, 9340, 9410, 9540
2b	Umbria, Marche, Lazio, N Abruzzo	MC, H, MS, DS	C, S, H	4000	9110, 9150, 9180, 9190, 91B0, 91E0, 9210, 9220, 9260, 9280, 92A0, 9340, 9540
2c	S Tuscany and Lazio	MC, H, DS	C, H	500	9110, 9150, 9180, 9190, 91E0, 91F0, 9220, 9260, 9280, 92A0, 9330, 9340, 9540
3. Southern Italy and Sicily (Mediterranean)					
3a	S Abruzzo, Molise, Apulia	MC, DC, MS, DS, G, H, B, D, P	C, S, G, D	2700	9180, 91B0, 91E0, 91F0, 9210, 9220, 9250, 9260, 9280, 92A0, 92D0, 9320, 9330, 9340, 9350, 9510, 9530, 9540
3b	Campania, Basilicata	DC, G, DS	C, G	2000	9180, 91B0, 91F0, 9210, 9220, 9260, 9280, 92A0, 92D0, 9320, 9340, 9390, 9510, 9540
3c	Calabria	DC, G	C, G	1000	9180, 91E0, 9210, 9220, 9260, 9280, 92A0, 92D0, 9320, 9330, 9340, 9510, 9530, 9540
3d	Sicily (Monti Nebrodi)	MC, DC, MS, DS, G	C, S, G	1500	9150, 91B0, 91E0, 9210, 9220, 9260, 92A0, 92D0, 9320, 9340, 9390, 9330, 9540
4. Sardinia (Mediterranean)					
4a	Gallura, Sulcis and Sarrabus mountains	MC, G	C, G	5500	91E0, 92A0, 92D0, 9320, 9340, 9390, 9330, 9540, 9580
4b	North and south lowlands	DS	S	4000	91E0, 92A0, 92D0, 9320, 9340, 9330
4c	Hills and plateaus of the central areas	DS	S	6000	91E0, 92D0, 9320, 9340, 9330
4d	Central-eastern Gennargentu	C, S, G, P	C, S, G	3500	91E0, 9260, 92A0, 92D0, 9320, 9340, 9390

^a Main geographical territories of presence. TN=Trento province; BZ=Bolzano province; FVG=Friuli-Venezia-Giulia.^b MC: Meat cattle; DC: Dairy Cattle; DS: Dairy Sheep; MS: Meat Sheep; G: Goats; H: Horses; B: Buffalos; D: Donkeys; P: Pigs.^c Presence of indigenous breeds of Cattle (C), Sheep (S), Goats (G), Horses (H), Buffalos (B), Donkeys (D) or Pigs (P).^d Area is approximate; potential area can be larger.

The Alps are considered a centre of biodiversity for Europe. They host about 4500 plant species of which almost 400 are endemic (Theurillat, 1995). A large part of biodiversity therefore linked to artificial or semi-natural environments and to traditional land use (Giacomini and Pignatti, 1955).

On the Alps, the deciduous forests usually occupy the less elevated stations and characterize the landscape of the valleys and the Prealps with an oceanic bioclimate, where the conifers tend to thrive at a higher altitude. The beech woods of the northeast Alps and partly those of Central Alps show the bond with the mesophile beech communities of the Illyrian region. Along the rest of the Alps they present more affinities with central European woods. The greater specificity of Alpine forest vegetation is due to these conifer woods of the class *Vaccinio-Picetea* such as spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) formations. At a higher altitude, the subalpine spruce forests gradually became an open forest with European larch (*Larix decidua*) and arolla pine (*Pinus cembra*). The shrub layer is dominated by Alpenrose (*Rhododendron ferrugineum*), bilberry (*Vaccinium myrtillus*) and Mountain cranberry (*V. vitis-idaea*). Between the treeline and the grasslands formations, a belt of twisted bushes is present characterized by Mountain juniper (*Juniperus alpina*), Bearberry (*Arctostaphylos uva-ursi*) and again by Alpenrose. In some areas, primary shrubs include prostrate bushes, with *Pinus mugo* and *Rhododendron hirsutum* (Biondi, 2007). Between 1800-2000 m, above treeline, the vegetation is represented by alpine acidophilous grasslands with *Carex curvula*, *Minuartia recurva*, *Hieracium glanduliferum* and *Nardus stricta* prairies strongly linked to grazing, with *Geum montanum*, *Arnica montana*, *Avenella flexuosa* and rare species such as *Nigritella nigra* and *Leuchorchis albida*. At the same altitude, on calcareous substrata, the dominant species are *Sesleria varia*, *Festuca violacea*, *Agrostis alpina* and *Trifolium thalii* (Montacchini *et al.*, 1982; Mondino, 2003).

Pastoral activities have been practiced for millennia; pre-existing shrublands and forest were cleared or burned to increase the availability of wide-open grasslands for livestock. Nowadays, depopulation of rural areas and corresponding reduction of stocking rates is a long-term trend that peaked after the Second World War. Cavallero *et al.* (1997) highlight that in 1961 the grassland surface in the mountain areas of Northern Italy took up more than 1.8 million hectares. In thirty years it was reduced on average more than 33% with the lowest values in Valle d'Aosta and the provinces of Bolzano and Trento and the highest in Liguria and Friuli-Venezia-Giulia. In the same time, the livestock in the mountain areas, that in 1961 was of some 900000 LU, decreased of about 28%, mainly as a consequence of cattle reduction. Nowadays abandonment is widespread throughout the Alps and is one of the major driving forces behind changes in vegetation types and ecosystem functions and dynamics (Cernusca *et al.*, 1999; Dirnböck *et al.*, 2003; Laiolo *et al.*, 2004). The LSGS areas of this sector include a diversified pattern of habitats and

site conditions during one grazing period. The LSGS in the Italian Alps include protected areas and ecotones, which are under pressure of overgrowth by woods and shrubs. In order to promote sustainable pasture utilization, Bassignana and Bornard (2001), Ziliotto *et al.* (2004), Miori and Sottovia (2005) and Cavallero *et al.* (2007) recently defined the agronomic characteristics of the main pasture types of Western and Eastern Alps and the management tools useful for their management and conservation. Some authors provided information concerning minimal grazing able to control the encroachment by shrubs and trees in abandoned grassland (Talamucci *et al.*, 1999; Cavallero *et al.*, 2000; Reyneri *et al.*, 2000; Staglianò *et al.*, 2000; Cereti and Rossini, 2001; Lombardi *et al.*, 2001). Others addressed the grazing of longtime abandoned pastures (Cavallero *et al.*, 1983; Acutis and Cavallero, 1988; Grignani and Dufour, 1990; Puccio *et al.*, 2007).

The Northern Italian sector includes three main sub-sectors with some similar but also some differential LSGS and vegetation types (Table 2) in which total LSGS area takes up some 6200 km² with mean stocking rate of some 0.45 LU/ha. The Western sub-sector includes the Italian regions of Valle d'Aosta, Piedmont and Liguria (**1a**). Two national parks (Gran Paradiso in Valle d'Aosta and Val Grande in Piedmont) and some regional protected areas are included. The current LSGS take up some 3000 km² with mean stocking rate of some 0.4 LU/ha. In Valle d'Aosta dairy cattle (local breed Pezzata Rossa Valdostana) is dominant, while a more differentiated system also based on different local breeds is more common in the other regions, with major importance in Piedmont. In this region in addition to a dairy cattle system (local breeds are Pezzata Rossa d'Oropa, Piemontese, Pustertaler-Barà and Tarina), is still operating a meat cattle production (mainly using the local breed Piemontese) compared to Liguria where livestock is undergoing a strong reduction and larger rangelands are under abandonment (Grignani and Dufour, 1990). Land in private property is dominant (80%) with summer grazing in upland pastures (2-4 months) associated to autumn and spring grazing in the lowlands. Additional feeding of forage conserves (hay or silage) is required during indoor winter period. Milk produced in the upland traditionally is transformed to make Fontina PDO (Product Denomination Origin) in Valle d'Aosta and consistent quantity of PDO and traditional cheeses in Piedmont such as Ossolano and Ossolano d'Alpe, Toma Piemontese, Castelmagno, Raschera, Bra and Taleggio (Battaglini *et al.*, 2004). In the Western Alps and in the surroundings Piedmont areas a traditional sheep and goat system based also on local breeds is still operating, both as sedentary breeding (mainly milk-oriented) and as itinerant flocks (mainly meat-oriented and based on local Biellese breed and its crossbreeds) between mountain pastures and the lowlands where conditions for nomadic movements still occur (Fortina, 2007). Some mixed systems, such as sheep-goats or others, can be also differentiated in this sub-sector. Cattle are permanently herded and, due to increasing presence of stray dogs and wolves, shepherding is increasing for sheep and goats. Nowadays the trend in land use is a dramatic abandonment of formerly

grazed areas, especially on those far-reaching grounds. In abandoned pastures, shrubs such as *Berberis* spp., *Rhododendron* spp., *Juniperus* spp., *Alnus* spp., *Salix* spp., *Pteridium aquilinum* and European larch are rapidly encroaching from field borders and colonizing previously open habitats (Cavallero *et al.*, 1997). Grazing management greatly affects vegetation changes and is able to control shrubs and trees encroachment both in the montane and sub-alpine belts (Acutis *et al.*, 1989; Reyneri *et al.*, 1994, 2000; Cavallero *et al.*, 2000; Lombardi and Cavallero, 2000).

The Central sub-sector takes up large areas of Lombardy (**1b**) where the Stelvio National Park and some regional protected areas are included. The actual LSGS area takes up some 1400 km², with an overall stocking rate of some 0.35 LU/ha, in which cattle production is dominant (60-80%), both for dairy and meat, compared to sheep and goats. In the upland farms (grazing for 2-4 months), many PDO and traditional cattle cheeses are produced such as Bitto PDO, Formai de mut PDO, Bagoss, Tombea, Grasso d'Alpe, Nostrano di malga, Nostrano di Valtrompia, Scimudin and Valtellina Casera PDO (Corti, 2004). Cattle are permanently herded and sometimes their grazing is followed or combined with sheep, goats and horses. Public land is dominant and co-operative property, almost absent in Western regions, are instead widespread in Central Alps (Cavallero *et al.*, 1997). In Lombardy, traditional sheep and goat systems are prevalently located in the mountain area. The goat system is mainly extensive and based on rearing of local breeds (i.e., Alpina, Lariana, Frisa valtellinese, Ciavenasca, Bionda dell'Adamello, Orobica, Verzaschese, Camosciata delle Alpi) and mostly oriented to milk production for pure or mixed (with cow's milk) cheeses and meat products such as milk-kid, salami and "violini" ham (Panzitta *et al.*, 2007). The sheep systems, mainly meat-oriented (Bergamasca and Biellese breeds), still practice vertical trasterminance (3/4 of total) between the mountains and the plain areas of Lombardy or Emilia Romagna (Corti, 2007) or sometimes, in very far-away areas of Tuscany (Argenti *et al.*, 1996). Large flocks (on average, about 900 heads) are normally moved by lorries, but sometimes also on foot especially during the autumnal descent. On this matter, the shepherds claim for protected ways for flock mobility and fewer limitations to the traditional use of forage resources along the rivers (Corti, 2007). In this sense, LSGS is mainly a service for nature conservation, but additional habitat management, including bush control (Corti and Maggioni, 2002; Maggioni *et al.*, 2004; Della Marianna *et al.*, 2007), is required for the mountain of high nature value farmland. As in the Western Alps, due to increasing presence of stray dogs, wolves and some other predators (including bears and birds of prey), shepherding is also increasing for sheep and goats.

The Eastern sub-sector comprises large tracts of Veneto and Friuli-Venezia-Giulia regions and of the Autonomous Provinces of Bolzano and Trento (**1c**), in which two national parks (Stelvio and Dolomiti Bellunesi) and many other protected areas are

included. The actual LSGS area takes up some 1800 km², with an overall stocking of some 0.55-0.67 LU/ha. Dairy cattle and breeding of heifers in mountain areas are dominant and still based on the rearing of local breeds (i.e., Rendena, Grigio alpina, Bigia Alpina, Pezzata Rossa Friulana) and characterized by seasonal migration between upland and lowland greater (some 40 km) than in other regions. Land property is under private, public and cooperative ownership and more than in other alpine sectors, the upland pastoral infrastructures are restructured by public support (Dovier *et al.*, 2006). Regional marketing carried out cooperatively for the production of Asiago and of many other quality cheeses produced in uplands (i.e., Asiago d'Alvevo vecchio, Sprezza, Nostrano di Val di Sole, Vezzena, Nostrano di Primiero, Puzzone di Moena, Formai de Malga). Starting from the seventies, mountain dairy farming in some districts was affected by deep transformations of the traditional system based on the use of local forages (Cozzi *et al.*, 2006). Driven by favorable milk price and by the low cost of feeds, intensive systems with specialized breeds and new production models increased. Similar trend was observed on dairy farms of the Po valley from which cattle are often transferred to Alpine pastures during summer and concentrates replaced hay, pastures and top quality forages like lucerne or corn silage. This produced eutrophication and a strong reduction of pasture utilization, with considerable effects on grasslands and landscape characteristics (Rigoni Stern and Da Ronch, 2006). In the specific case of Asiago highland, the occurrence of these negative impacts required the application of disciplinary regulations to safeguard the grasslands of public property (Cozzi *et al.*, 2004). A traditional and extensive sheep and goat production, based on local breeds (Camosciata delle Alpi, Bionda dell'Adamello, Pezzata Mochena among the goats; Brogna, Alpagota, Lamon, Carsolina and others faced with the danger of extinction among the sheep) used for quality cheese/meat production, is still active in the mountain areas of this sector, but interested by strong number reduction in the last decades (Pastore and Fabbris, 1999; Pastore, 2005; Loszach *et al.*, 2007). Mostly in Veneto and Trento provinces, some large sheep flocks (more than 1000-1500 sheep) mainly meat-oriented (Bergamasca and Biellese breeds), are still itinerant between the mountain (4-5 months) and the Venetian plain areas. During centuries, the familiar altitudinal transhumance was an important activity in this Alps' sub-sector of Italy. For a large part of villagers, grazing of commonly used land formed the main way of living. This activity has diminished continuously in the past 150 years and dramatically in the last 25 years. Understocking, modified grazing management and abandonment greatly affected vegetation changes (Sabatini and Argenti, 2001; Da Ronch *et al.*, 2002, 2005a, b, 2006; D'Ottavio *et al.*, 2003; Ziliotto *et al.*, 2003; Scotton and D'Ottavio, 2005) while the well designed utilization of the grasslands was demonstrated to be compatible with their high natural value conservation (Scotton *et al.*, 1996; Rodaro *et al.*, 1998).

The central Italian sector

The central Italian sector includes tracts of the geographical regions of Emilia-Romagna, Tuscany, Umbria, Marche, Lazio and Abruzzo, which, apart from the highest areas of Gran Sasso and Majella Mountains, are mainly located in the Continental (Adriatic side) and Mediterranean (Tyrrhenian side) biogeographical regions. The main lithologies consist of limestone, compact sandstones-conglomeratic rocks, marl, and crystalline rocks. From the bioclimatic point of view, the sector falls in the Temperate and the Mediterranean regions and presents a high level of diversification. It includes the following bioclimates: temperate oceanic at middle and high elevation of the Apennines; temperate semicontinental in the inland valleys of the Apennine generally with an Adriatic aspect; temperate oceanic semicontinental in the hilly zones of the mid-Adriatic and inland valleys with a Tyrrhenian aspect; transitional temperate oceanic in all the valleys of the Tyrrhenian Anti-Apennine, Mediterranean oceanic in part of the coastal areas, transitional temperate oceanic-semicontinental in the plains and first hilly spurs of mid and lower Adriatic (Blasi and Michetti, 2007). The climate, in general, is characterized by higher mean temperature, by precipitation concentrated during spring, winter and autumn and by water deficit and aridity occurring during summer when adequate forage production from grasslands is available only at the highest altitude (Cavallero *et al.*, 1992; Ziliotto *et al.*, 1992).

Throughout the sub-Mediterranean and temperate zones that cover large areas along the central Italian sector, forest vegetation is mainly represented by mixed deciduous formation of the *Quercus-Fagetum* class, order *Quercetalia pubescentis*. It includes woods dominated by hop hornbeam (*Ostrya carpinifolia*) and by downy oak (*Quercus pubescens* s.l.). On acid soils the forests of the alliance *Teucrio siculi-Quercion cerridis*, with Turkey oak (*Quercus cerris*) and Hungarian oak (*Q. frainetto*) represent the main potential vegetation. The mountain zone is characterized by the potentiality for beech forests (*Fagus sylvatica*) of the two alliances *Aremonio-Fagion*, with the suballiance *Cardamino kitaibelii-Fagion sylvaticae*, and *Geranio versicoloris-Fagion sylvaticae* (Biondi, 2007). In the Mediterranean bioclimatic areas, the woody and shrubland vegetation is represented by the formations of the class *Quercetalia ilicis*. The main associations of holm oak forests are represented by *Cyclamini repandi-Quercetum ilicis* over the Tyrrhenian zone and the *Erico-Quercetum ilicis* on crystalline substrates. Along the Adriatic slope mixed associations of sclerophyllous evergreen and deciduous, such as *Fraxino orni-Quercetum ilicis*, *Ostryo-Quercetum ilicis* and *Cephalanthero longifoliae-Quercetum ilicis* are also present (Biondi, 2007). In the central Italian sector the secondary prairies of the class *Festuco-Brometalia*, order *Brometalia erecti*, have their higher level of presence in the Italian context. They include xerophile and semi-mesophile, mostly calciphile grassland formations rich in Mediterranean species (*Phleo*

ambigui-Bromion erecti), chamaephytic pioneering pastures developing on calcareous-marly and marly arenaceous substrates (*Xerobromion*) and mesophile non calcicole grasslands hosting boreal species (*Bromion erecti*) (Biondi *et al.*, 1995). Semi natural dry grasslands scrubland facies on calcareous substrate of the *Festuco-Brometalia* are frequently very rich in orchids, such as: *Aceras anthropophorum*, *Anacamptis pyramidalis*, *Coeloglossum viride*, *Dactylorhiza latifolia*, *Epipactis atrorubens*, *Gymnademina conopsea*, *G. widderi*, *Neotinea maculata*, *Ophrys* ssp., *Orchis* ssp., *Pseudorchis albida*, *Serapias lingua*, *S. parviflora*, *Spiranthes spiralis* and *Traunsteinera globosa* (Biondi, 2007). These formations are considered priority habitats (EC, 1992) named “*important orchid sites”. They are characterized by a dense suite of Orchidaceae or by a relevant population of one species considered uncommon at national level. In Italy, this habitat is present especially in the Apennine, in the temperate bioclimate, along the sub-Mediterranean and hilly ranges. Their natural dynamic, upon cessation of use, leads the development of shrub communities of the class *Rhamno-Prunetea*. On siliceous substrates, grasslands dominated by *Nardus stricta*, of the *Ranuculo-Nardion alliance*, are often present especially in the high Tuscan-Emilian range (Biondi, 2007).

Livestock breeding has been one of the main economic activities practiced in the territory of the Italian Apennines. In Central Apennines, the influence of the pastoral activities on the environment results extremely meaningful. In order to increase the pastureland areas, mainly grazed by transhumant sheep (Boscaglia, 1920; Censi Mancia, 1930; Pullè, 1937), large portions of the pre-existing forests of the mountain belt (1000-1800 m) were cleared or burned (Pedrotti, 1969). The strong crisis of the traditional livestock breeding occurred after the second half of the past century in Central Italy (Santilocchi and D’Ottavio, 2005), strongly reduced the stocking rates and changed the grazing management (D’Ottavio and Scotton, 2002b) or caused the abandonment of the pastoral practices in large areas. These aspects caused modifications of the environmental, agronomic and landscape characteristics of the grasslands (D’Ottavio *et al.*, 2000, 2004; D’Ottavio and Scotton, 2002a). Among these, intensive processes of shrub and tree encroachment (mainly *Juniperus communis* and *J. oxycedrus*, *Spartium junceum* and *Rosa canina*) in large tracts of Central Apennines. Nowadays, the management of the vegetation dynamics is highly required in relation to the different functions assigned to the grasslands. Apart from their environmental and landscape role, in some pastoral districts grasslands still have a very remarkable productive importance (D’Ottavio and Scotton, 2002b). To produce positive effects both for pastoral farms and for nature conservation, the definition of the agronomic characteristics of the pastures and the application of grazing planning methods are required. With this regard, the assessment of the pastoral value and the carrying capacity of the different pastures (Daget and Poissonet, 1971; Plantureux *et al.*, 1992) are advisable. This method is normally used both in alpine context (Cemagref, 1983, 1987; Bornard, 1991; Jouglet

et al., 1992; Jouglet, 1999; Bassignana and Bornard, 2001; Cavallero *et al.*, 2007) and in the Apennines (Bagella, 2001_{a,b}; D'Ottavio *et al.*, 2005_{a,b}). Roggero *et al.* (2002) revised the definition of the specific indices of the forage plants used for the calculation of the pastoral value. In addition, the planning of pastoral activities also requires pasture improvement practices (with particular regard to weeds control, including shrubs cutting) and grazing management in order to fit the stocking rates to the pastures productivity (Staglianò *et al.*, 2001). It also requires the maintenance and improvement of the pastoral infrastructures (roads, barns and drinking troughs) as normally performed in some alpine sectors, which nowadays are mainly lacking, inadequate to the basic needs or in bad maintenance conditions. Adequate competences and resources should be addressed to improve quality of life of the shepherds, mostly immigrants, in terms of housing and social integration, including knowledge of Italian language. The complexity of the body of legislation, which regulates the agro-silvo-pastoral activities in mountain areas and its apparent inadequacy in the light of the current socio-economic and environmental conditions, make the management of these areas difficult. The need to identify the problematic aspects linked to this application, and the competence of powers between the different public bodies involved in the territory planning and control is propaedeutic to legislation adjustments.

The total LSGS area in the Central Italian sector takes up some 6000 km², mainly located in Central Apennines, with mean stocking rate of some 0.3 LU/ha. Private, public and collective property regimes are present and private ownership and management of herds/flocks is more common. Shared grazing facilities in collective and public properties include water supply as well as marketing of livestock products and celebration of traditions connected with LSGS, promoted by farmers' associations and tourism bodies.

The Central Italian sector includes three main sub-sectors with some similar but also some differential LSGS and vegetation types (Table 2). The first sub-sector comprises the hilly and mountain areas under LSGS in Tuscany and Emilia-Romagna (**2a**) where two national parks (Appennino Tosco-Emiliano and Foreste Casentinesi-Monte Falterona-Campigna) and many other regional protected areas are present. The actual LSGS area takes up some 300 km² with an overall stocking rate of 0.2-0.4 LU/ha. Meat cattle (including Chianina and Romagnola local breeds) are common in hilly and mountain areas. During summer (4 to 6 months) in upland pastures (800-1400 m) continuous stocking and occasional shepherding is adopted. Spring and autumn grazing is adopted in the lowland, where the herds move back near the farmyard for winter time, when they are kept indoor and fed mainly with hay and/or silage. Sheep production is mainly milk-oriented (Sarda breed) by sedentary farms in hilly and lowland areas for Pecorino cheese production. Mainly in Tuscany, some seasonal sheep migration (vertical transhumance) between the lowland and upland pastures also using

local breeds (Garfagnina, Massese) is still operating. Flocks practicing transhumance in Emilia-Romagna almost disappeared in the seventies (Manfredini, 1976). Sheep grazing could actively contribute to the management of the firebreak lines present in the hill areas of Tuscany (Talamucci *et al.*, 1995). In spite of consistent reduction of pastoral and agricultural activities in large marginal areas in hills and mountain of Tuscany some experiences of pasture rehabilitation are undertaken (Staglianò *et al.*, 1997; Natali *et al.*, 2006b) and pasture management planning is required in order to promote biodiversity (Natali *et al.*, 2006a; Targetti *et al.*, 2006).

The second sub-sector comprises a much larger area under LSGS (4000 km²) including Lazio, Umbria, Marche and Northern Abruzzo (**2b**) where two national parks (Monti Sibillini and Gran Sasso-Monti della Laga-Gran Sasso) and many other regional protected areas are present. Meat-oriented cattle in high-hilly and mountain areas (often grazing with horses) is mainly based on local breeds (mostly Marchigiana, but also Chianina and Maremmana) by sedentary farms adopting short-distance vertical *trasterminance*. From April-May to October-November, animals graze pastures at progressively higher altitude mostly according to continuous stocking and occasional shepherding, and move back to the farmyard for winter when animals are kept indoor (cattle) or in paddocks (horses). In this sub-sector, sedentary (mainly milk-oriented) and itinerant (mainly meat-oriented) sheep systems are still present. Sedentary farms (in general 100-500, but also up to 1000 sheep), are mainly located in mountain areas where shepherds adopt vertical *trasterminance* to upland pastures (May-November) and keep animals indoor during the winter if grazing is not possible. Some local breeds (Appenninica and Fabrianese) are still present, while some others, as Merino-derived Sopravvissana used by transhumants from Monti Sibillini to Lazio, are mostly disappeared, but larger flocks are yet common in Abruzzo (Panella and Di Felice, 1994). A more specialized sedentary dairy system (Sarda sheep) is present in the coastal and hilly areas adopting grazing in large estates. The itinerant flocks (more than 500, but also up to 4000-5000 sheep) graze different grazing blocks during the year. In summer time, they use upland pastures located at the lowest altitude throughout the grazing period (June-beginning of autumn) and the highest pastures (up to 2400 m) during July and August. In autumn-winter they transfer progressively to lowlands of the different regions of Central Italy. Here sedentary grazing in large estates (mainly in Tyrrhenian coast) or itinerant grazing (mainly in Adriatic coast) is practiced. In both coastal areas, vertical grazing is common with seasonal farming units at different altitudes, continuous stocking and almost permanent shepherding. The forage balance can be improved by use of green cereals and lucernes (D'Ottavio and Scotton, 2002a, b; Santilocchi and D'Ottavio, 2005). The LSGS of this sub-sector include protected areas which are normally abandoned or understocked and under pressure of being overgrown by woods

such as in Monti Sibillini National Park, where grazing helps avoiding wood recovery and maintaining open landscapes (D'Ottavio and Scotton, 2002a, b).

The third sub-sector comprises the LSGS area (some 500 km²) between Southern Tuscany and Northern Lazio (Maremma) (2c) which includes Maremma Natural Park and other regional protected areas. Large tracts of land were occupied by Mediterranean maquis, while the plain areas were marshy and affected by malaria. Given these conditions, large public, private or collective properties were devoted to extensive breeding: cattle on the maquis, buffaloes on marshlands and sheep in the transition areas (Santilocchi and D'Ottavio, 2005). Transhumance was often applied here to sheep breeding between autumn and spring, while during summer they were transferred to pastures of Central Apennines. This situation remained quite stable until the beginning of the 20th century. Starting from that time, important modifications occurred when large marshlands were vastly reclaimed. The high fertility of the reclaimed soil favored the development of very intensive farming. Easy commercial outputs were found in the rapidly expanding cities (Rome and Florence in particular). Sheep breeding gradually changed, due to an ever-increasing preference towards specialized breeds for milk production. Some itinerant flocks are still transferred in this area from the Apennines, adopting vertical trasterminance between the lowland and upland pastures. An extensive cattle system (based on Chianina or mixed cattle-horse of Maremmana breed) on fenced estates under occasional herding is facing a sharp decrease if compared to the past diffusion (CNR, 1988), but it's still able to contribute to avoid wood recovery and in maintaining open landscapes (Pardini and Rossini, 1997; Pardini *et al.*, 2002; Staglianò *et al.*, 2005).

The southern Italian and Sicilian sector

The southern Italian sector includes the southern part of the Abruzzo region and Molise, Apulia, Campania, Basilicata, Calabria, and the island of Sicily, which are located in the Mediterranean biogeographical region. The main lithologic substrata consist of limestone, compact sandstones-conglomeratic rocks, marly and crystalline rocks. From the bioclimatic point of view, the sector falls in the temperate and the Mediterranean regions, and presents a high level of diversification. The following bioclimates are present: temperate oceanic at middle and high elevation of the Apennines and the high mountains of Sicily, temperate oceanic semicontinental in the inland valleys of the Apennine, transitional temperate oceanic in all the valleys of the Ionian and Tyrrhenian anti-Apennine and Sicily, transitional temperate oceanic-semicontinental in the plains and first hilly spurs of mid and lower Adriatic and Ionian and in some inland areas of Sicily, Mediterranean oceanic and transitional Mediterranean oceanic in Sicily (Blasi and Michetti, 2007). The climate, characterized by high winter rainfalls and high summer

water deficit and aridity during 2-6 months with higher mean temperatures compared to the other Italian sectors, and it is responsible of the production stasis of the pastures during the summer period (Cavallero *et al.*, 1992; Ziliotto *et al.*, 1992).

Throughout the sub-Mediterranean and temperate areas the vegetation wood cover is mainly represented by mixed deciduous ascribed to the alliance *Carpinion orientalis* (class *Quercus-Fagetum*). It includes woods dominated by hop hornbeam (*Ostrya carpinifolia*) and by downy oak (*Quercus pubescens* s.l.). On acid soils, the forests of the alliance *Teucro siculi-Quercion cerridis*, with Turkey oak (*Quercus cerris*) and Hungarian oak (*Q. frainetto*) represent the main potential vegetation. The mountain vegetation zone is characterized by the potentiality for beech forest (*Fagus sylvatica*) of the endemic alliance *Geranio versicoloris-Fagion sylvaticae*. In southern Apennine and Sicily, this alliance presents several associations such as *Anemone apenninae-Fagetum*, *Aceri lobelii-Fagetum* and *Doronicum columnae-Fagetum*. In the Mediterranean bioclimatic areas, the woody and shrubland vegetation is represented by the formations of the class *Quercetea ilicis*. The main associations of holm oak forests are *Cyclamini repandi-Quercetum ilicis* over the Tyrrhenian zone and *Erico-Quercetum ilicis* on crystalline substrates. Along the Adriatic slopes mixed associations of sclerophyllous evergreen and deciduous, such as *Fraxino ornitho-Quercetum ilicis*, *Ostryo-Quercetum ilicis* and *Cephalanthero longifoliae-Quercetum ilicis* are also present (Biondi, 2007).

In southern Italy, the deep summer drought, typical of the Mediterranean climate, has historically relegated intensive farming to small irrigated areas. In this sector of Italy, large areas of public property are used by the local communities. These factors favored the setting up of extensive livestock breeding systems, also including various forms of long-distance sheep transhumance, actually strongly reduced and disappeared in their traditional ways. Large tracts of the ancient ways (*tratturi*) to transfer the transhumant flocks from Abruzzo and Molise mountains to plain areas of Apulia are actually mainly abandoned and under pressure of being overgrown by shrubs and woods, or unlawfully used, for urban settlements or other land use or interrupted by road networks. Nowadays, in spite of the strong crisis of the livestock breeding that occurred during the second half of the past century, LSGS still represent a strategic element for the rural development of these areas because of many reasons. The grazing activities are directly based on the use of environmental resources (pastures, woods and arable lands) and contribute to landscape and nature conservation, wildfires prevention and to soil protection. They provide much quality meat, cheese products, in some areas are still the main source of income of rural communities, and allow integrating the earnings deriving from extra-agricultural activities such as agritourism.

The Southern Italian sector includes four main sub-sectors with some similar but also some differential LSGS and vegetation types (Table 2). The whole area managed

by LSGS takes up some 8000 km² in which private, public and collective property regimes are present. Shared grazing facilities in collective property include water supply as well as marketing of livestock products and celebration of traditions connected with LSGS, promoted by farmers' associations and tourism bodies. LSGS in Southern Italy shared many features of the production system and some of the objectives, with some differential characteristics as afterwards described.

In the sub-sector of Southern Abruzzo, Molise and Apulia (**3a**) the actual LSGS area takes up some 2700 km² with overall stocking of about 0.4-0.6 LU/ha. Two national parks in Abruzzo and Molise (Majella and Abruzzo-Lazio-Molise) and two in Apulia (Gargano and Alta Murgia) are included in LSGS. In Southern Abruzzo, Molise and Northern Apulia, *Quercus virgiliana* woods mainly represent potential vegetation. The Gargano is the Apulian area with highest coverage of woodlands. From the coast to the inland, a succession of different kind of woods is present: *Pinus halepensis* (*Pistacio lentisci-Pinetum halepensis*), *Quercus ilex* (*Cyclamino hederifolii-Quercetum ilicis*), *Quercus cerris* (*Physopermo verticillati-Quercetum cerris*) and *Fagus sylvatica* (*Aremonio-Fagetum sylvaticae*) woods. The hilly belt is characterized by mixed downy oak forests dominated by *Quercus virgiliana* and *Q. pubescens*. In the Murgia area it is very peculiar the presence of *Quercus trojana* forests (Falinski and Pedrotti, 1990; Biondi *et al.*, 2004). In this sub-sector, some distinctive systems are present. Itinerant flocks, mainly meat-oriented also based on the local breed Gentile di Puglia, are mainly present in S Abruzzo and Molise in the old transhumance areas. The seasonal flock mobility between mountain pastures and the lowlands of N Apulia is now carried out by short-term migration or by lorries and, starting from the seventies, mobility along *tratturi* is mostly disappeared. Sheep farms, mainly milk-oriented, sedentary or adopting short-distance vertical movements are commonly present in large tracts of Apulia where some local breeds (Altamura and Leccese) are used. Cattle breeding are mostly based on Marchigiana in S Abruzzo and Molise and on Podolica breed in Apulia (Gargano promontory) which provides typical cheeses as Caciocavallo podolico and Scamorza, and butter (*Manteca*). Vertical trasterminance and movements are more commonly adopted for Marchigiana and for heifers of dairy herds grazing during summer on mountain areas, also remote from the farmstead. Winter activity is based on the pasturelands near the farmyard, complemented with indoor feeding. Besides, a mixed system is usually present in Apulia, where cattle's grazing is combined with sheep, goat and sometimes other animals. In these systems of Apulia, pastures provide feeding during autumn-winter season and forage stocks for warmer period (late spring and summer season) are mainly represented by ungrazed pasturelands. In Apulia, a traditional goat (Garganica and other local breeds) and Buffalo production (used for Mozzarella di Bufala Campana) represent LSGS in Gargano. A donkey production (Martina Franca breed) is based on a rough grazing in the Murge hilly areas with an interesting and increasing production of

milk used for cosmetic and pediatric use. The pastureland area represent about the 10% of the Apulia land with low agronomic income but extremely important for maintaining and sustaining the local and typical productions, for landscape conservation and environmental protection. Grazing on pasturelands and on Mediterranean forest helps to reduce danger of wildfires and to maintain open pasturelands in which many species, due to their low number, have been registered in the red list of the Italian Ministries. The limited availability of feeding resources near to the farmyard is however responsible of widespread overgrazing and the improper governance of public pastureland is a destabilizing factor (Petrocelli, 1991). This strongly affected the floristic composition of the swards, reducing the percentage of species with high qualitative characteristics.

The sub-sector of Campania and Basilicata (**3b**) includes a LSGS area of some 2000 km² in which two national parks (Cilento-Vallo di Diano and the N part of Pollino) and some other regional protected areas are present. Livestock breeding is carried out in most of the territory, from the coast to the internal hilly areas and to the State-mountain pastures, and characterized by a complex and articulated structure. In addition to intensive and specialised farms mostly diffused in plain areas (e.g., Buffalo system for Mozzarella di Bufala Campana production), traditional and pastoral systems are still operating in the LFA providing high quality and labelled cheeses as Provolone, Caciocavallo and Provolone. In this sub-sector, some distinctive systems are differentiated. Podolica cattle system is present in the hilly and mountain areas of Avellino and Salerno provinces in Campania and of Potenza and Matera in Basilicata. Podolica is mainly meat-oriented and so milk production is normally very low if compared with high productive dairy cattle. The amounts of its typical dairy products are small and their processing performed mostly at the farm level. Podolica breeding is traditionally carried out in the marginal areas of S Apennines adopting rough grazing during all the year and forms of vertical trasterminance. Goat systems are mainly located in the coast-areas such as Salerno province and in particular in the protected area of Cilento and Vallo di Diano, where some local breeds (Capra del Cilento) are still reared. The mostly sedentary breeding includes a rough grazing during all the year in pastures and forestlands. A sheep system, mainly milk-oriented, has still an important role in the large tracts of the mountain territory adopting short-distance trasterminance and vertical movements. Livestock breeding has still an important role in the local economy. In confirmation of that, in Campania around 38% of used agricultural surface is devoted to meadows and pastures, and a large arable land to forage crops. In addition, forestlands that takes up some 33% of the total agricultural surface, have a significant role in the breeding activities. In fact, due to their high adaptability both Podolica cattle and the goat are able to make use of scattered forests of Mediterranean maquis. In spite of the productions of relatively poor pastoral systems, grazing has still a fundamental role in large territories of this sector of S Italy. LSGS contribute to maintain the landscape characteristics otherwise addressed to

abandonment and environmental degradation and to mitigate the demographic decrease in the LFA.

In the sub-sector of Calabria (**3c**) the actual LSGS area, some 1000 km², includes three national parks (Pollino, Sila and Aspromonte) and the regional protected areas of Natural Park of Serre affected by LSGS. Podolica system, that has similar characteristics of those described in the other sub-sectors of Southern Italy, is mostly present between the hilly and mountain areas of Cosenza and Catanzaro provinces. This system includes large tracts of Sila and Serre parks, where a vertical trasterminance is commonly adopted. A traditional goat system (based also on indigenous breeds of S Italy), sometimes includes also sheep and goats as dominant flocks (Brandmayr *et al.*, 2002). It is more common in Ionic side of Catanzaro and Kroton provinces and in Reggio Calabria where vertical mobility is still common between the hilly and mountain areas of the S Apennines (Aspromonte). Black pine forests (*Hypochoerido-Pinetum calabricae*), is the main peculiar vegetation of this sector. More than 50% of the area is included as LFA, mainly in mountain handicapped environments where forest overgrowth is common. On the opposite, as described for other sectors of Southern Italy, some problems of overgrazing can be detected in the lowland pastures.

In the Nebrodi mountains of Sicily (**3d**), a protected area is included (Park of Nebrodi) and a mixed LSGS including cattle, sheep and goats is operating under strong cultural traditions on some 1500 km². The main forest vegetation types are represented by cork oak forests (*Genisto aristatae-Quercetum suberis*); holm oak forests (*Teucrio siculi-Quercetum ilicis*); deciduous oak forests (*Festuco heterophyllae-Quercetum congestae*, *Quercetum gussonei*, *Arrhenathero nebrodensis-Quercetum cerridis*); beech forests (*Anemono apenninae-Fagetum*), partly with *Abies alba* and *Abies nebrodensis*, the endemic fir of the Nebrodi (Brullo *et al.*, 1996; 1999). The system is the basis of indigenous livestock products such as Provola dei Nebrodi and Ricotta infornata cheeses. A traditional vertical trasterminance between lowlands and uplands is practiced. Each grazing area (in both uplands and lowlands) is split in large blocks subjected to rotational stocking. Such management allows the grazing for the whole year round and only for very short period during winter animals are sheltered. These LSGS play an important role in maintaining a particular habitat pattern of open spaces and avoiding shrubby encroachment in Mediterranean forest landscape. Grazing helps to reduce risk of forest fires as well as to maintain biodiversity, but sometimes the high stocking density represents a critical factor, also for forest regeneration. Grasslands host several orchids, some of which are endemic: *Ophrys lacaitae*, *O. oxyrrhyncos*, *O. sphegodes* subsp. *sicula*, *O. branbrancifortii* and *O. commutata*. In Sicily, some other large areas are affected by LSGS including protected regional areas such as Madonie and Etna Parks in which cattle, sheep and goats based on the extensive use of pastures and woodlands

provide high quality meat and dairy products (Provola delle Madonie, Ricotta infornata and Pecorino Siciliano PDO). Dairy cattle is dominant in Ibleo Highland (around 900 km²), based also on rearing of Modicana local breed grazing on spontaneous pastures during winter (Galvano and Furnari, 1986).

The Sardinian sector

Sardinia, located in a central position of the western Mediterranean area, with a surface of about 24090 km², is the second island of the basin. It is included in the Mediterranean biogeographical region (Rivas-Martínez *et al.*, 2001a), western Mediterranean sub-region and Corsican-Sardinian province (Arrigoni, 1983). The territory is mainly mountainous, but the average altitude is quite low (334 m). Relieves are represented by massifs divided by plateaux and plains which permit to recognize large regions which have had a relevant interest in land use and historical and cultural aspects of the territory (Mori, 1966). Three main bioclimate types are present in the island: transitional temperate oceanic on the highest mountains; Mediterranean oceanic along the coasts and transitional Mediterranean oceanic in the inland plains and first spurs (Blasi and Michetti, 2007).

Sardinia is considered a hotspot for plants in the Mediterranean region (Médail and Quézel, 1999). Its flora include 2400 entities, 5% of which are endemic to Sardinia and 4% to Sardinia, Corsica and some other Tyrrhenian areas (Arrigoni, 2006). Two National Parks are present: La Maddalena and Asinara.

The holm oak woods dominate the forest landscape of Sardinia (Pignatti, 1998), because *Quercus ilex* has a wide ecological amplitude on the island, ranging from sea level to above 1400 m (Camarda and Valsecchi, 1983). The following associations have been recognized (Arrigoni *et al.*, 1985, 1990; Biondi *et al.*, 2001; Bacchetta *et al.*, 2004a; Bacchetta *et al.*, 2009): *Pyro amygdaliformis-Quercetum ilicis*, which includes the edapho-mesophile holm oak and cork oak vegetation of the alluvial plains of a mixed clay-sand matrix, on moderately hydromorphic soils (e.g., Nurra and Alto Campidano); *Prasio majoris-Quercetum ilicis* which includes thermophile communities on different substrata under 400-500 m (e.g., Nurra, Logudoro, Montiferru, Gallura); *Galio scabris-Quercetum ilicis*, which includes evergreen woods located between 600 and 1000 m on different substrata (e.g., Gallura, Montiferru, Planargia Sulcis and central-eastern Sardinia); *Saniculo europaeae-Quercetum ilicis* which includes mainly the acidophilic woodlands of *Q. ilex* and *Ilex aquifolium* of the metamorphic and volcanic substrata of central-northern Sardinia between 660 and 1100 m (e.g., Goceano and Montiferru); *Aceri monspessulani-Quercetum ilicis* calcicole montane holm oak woods of the limestone substrata of central-eastern and southern Sardinia.

Regarding the forest vegetation of *Q. suber*, Sardinia alone has 90% of the Italian coverage of these woods, with about 100000 ha quantified in 1985 (Corona *et al.*, 1989). Only recently Serra *et al.* (2002) and Rivas-Martínez *et al.* (2003) have recognized for Sardinia, within the alliance *Quercion ilicis* (suballiance *Quercenion ilicis*), the presence of autonomous associations of *Q. suber*. Two associations were recognized (Bacchetta *et al.*, 2004a): *Galio scabri-Quercetum suberis*, which includes cork-oak meso-woods on granites and metamorphic substrata between 200 and 550 m in Gallura, Sulcis, Sarrabus and Iglesias, often subjected to intense use for the extraction of cork and/or as wooded pasture; and *Violo dehnhardtii-Quercetum suberis*, which includes the neutro-acidophile cork-oak meso-woods on volcanic substrata of north-western Sardinia, at altitudes between 50 and 700 m and mainly subjected to an intense pastoral use, with the formation of wooded pastures (Bagella and Caria, 2010).

Deciduous oak woods have been referred to three associations (Bacchetta *et al.*, 2004b): *Lonicero implexae-Quercetum virgilianae*, which includes thermophile communities on carbonated substrata mainly throughout Northern Sardinia; *Ornithogalo pyrenaici-Quercetum ichnusae*, more widely distributed in central-northern Sardinia on non carbonated substrata between 200-1000 m; *Glechomo sardoae-Quercetum congestae* on basalts, metamorphites and granite between 750-1000 m (Gennargentu, Barbagia, Montiferru and Goceano).

Perennial short grasslands of the Western Mediterranean alliance *Thero-Brachypodium retusi*, widespread in the island, have been referred mainly to the associations *Asphodelo microcarpi-Brachypodium retusi* (Biondi and Mossa, 1992; Biondi *et al.*, 2001; Bacchetta *et al.*, 2005, Biondi and Bagella, 2005). Perennial tall grasses of the class *Lygeo-Stipetea* have been referred to the associations *Phagnalo annotici-Lygetum sparti* (Biondi and Mossa, 1992), *Hyparrhenietum hirta-pubescentis* (Valsecchi, 1976; Arrigoni and Di Tommaso, 1991) and *Oryzopsis-Hyparrhenietum hirtae* (Biondi and Bagella, 2005). Perennial grasslands of the order *Brachypodio ramosi-Dactyletalia hispanicae* have been referred to the associations: *Anthyllido vulnerariae-Kundmannietum siculae*, *Loto cytisoidis-Dactyletum hispanicae*, *Dactylo hispanicae-Camphorosmetum monspeliaca*, *Scillo obtusifoliae-Bellidetum sylvestris* and *Scillo autumnalis-Bellidetum sylvestris* (Biondi *et al.*, 2001). Mountain grasslands of the Gennargentu massif belong to very rich in endemic communities of the class *Carici-Genistetea lobelii*: *Crepidobrachypodium pinnati* and *Festucetum morisiana* (Arrigoni, 1986). They host very rare taxa, such as *Armeria sardoae* subsp. *genargentea*, *Astragalus genargenteus*, *Bellium bellidioides*, *Carex caryophyllea* subsp. *insularis*, *Carlina macrocephala*, *Festuca morisiana*, *Hieracium soleriolanum*, *Poa balbisi*, *Plantago subulata* subsp. *insularis*, *Sagina pilifera*, *Santolina insularis*, *Thymus herba-barona*, *Trisetum gracile*, *Veronica brevistyla*, *Viola corsica* subsp. *limbarae*. Hygrophilous perennial grasslands trampled

and grazed, often temporary inundated have been referred to the association *Agrostio stoloniferae-Cyperetum badii* (Biondi and Bagella, 2005). They often host endemic species such as *Cerastium palustre*, *Carex caryophyllea* subsp. *insularis*, *Festuca morisiana*, *Oenanthe lisae*, *Ornithogalum corsicum*, and *Ranunculus cymbalarifolius* (Bagella and Caria, unpubl. data).

Pastures dominated by perennial grasses, prostrate chamaephytes and hemicryptophytes, and associated to adequate sheep grazing and manuring, belong to the class *Poetea bulbosae* (Ladero *et al.*, 1992; Farris *et al.*, 2007). They represent very productive and extensive anthropogenic Western Mediterranean communities, which dry up in early summer, grow fast with autumnal rainy season and remain green during winter (Rivas-Martínez *et al.*, 2001a). They are very important for biodiversity conservation hosting several endemic species such as *Crocus minimus*, *Morisia monantha*, *Ornithogalum corsicum* and *Romulea requienii* (Bagella and Caria, unpubl. data).

LSGS in Sardinia encompass some 15000 km² with a variety of sub-types all across the island. Cattle are dominant in the Gallura's mountains and goat in the hilly and mountain areas of Sulcis-Iglesiente and Sarrabus (**4a**). Intensive dairy sheep is present in the province of Sassari (Nurra, Logudoro) and in the south lowlands (**4b**). Semi-intensive dairy sheep and cattle are dominant in the hills of Planargia, Marghine, and Goceano (**4c**) and mixed grazing, including pigs, in Gennargentu's mountains (**4d**). Hill and mountains dominate the landscape. Vertical transhumance of herds/flocks from lowland pastures in winter to upland pastures in summer is frequent (Paoli, 2000; Bergeron and Paoli, 2003; Natale *et al.*, 2004; Ligios *et al.*, 2004).

Most grassland are under private ownership, but mountain pastures include large areas of public land such as Limbara, Monte Linas-Marganai and Sette-Fratelli (**4a**) or Sinis-Montiferru and Marghine-Planargia (**4c**). In these common lands, livestock farmers share grazing rights and agree on the partitioning of the grazing area. Main habitat types are upland pastures inclusive of Mediterranean forest and open bushland in the hilly and mountainous areas and cultivated pastures in the lowlands.

Subsidies have so far kept most systems viable even if at low-income conditions. Family business turnover is under threat, even if less than in other Italian systems, as young farmers have few alternative jobs due to insularity. The regional government provides consulting services and financial support (low grazing-fees in public lands), but private cheese making and cheese marketing co-operation is a main driver. Indigenous cattle breeds such as Sardo-Modicana or Bruno Sarda fit to harsh environments and are of interest for the production of quality cheese such as *Casizolu* from the Sardo-Modicana (Molle *et al.*, 2002).

LSGS include areas which are overgrown by woods. However, some hill or upland pastures can be under pressure of overgrazing. Stationary herds/flocks, mainly dairy

cattle and sheep, are frequently penned over the autumn and winter months and rarely move to upland. Complementary conserved forage, sometime from irrigated land, and manufactured feed rations are increasing (Fois *et al.*, 1999; Natale *et al.*, 2004).

Individual profiles of Greek LSGS

Only the Mediterranean biogeographical region is represented in Greece (132000 km²) (EC, 2003; Metzger *et al.*, 2005) (see Map 3). Climate and topography, however, are very variable both in the mainland and the numerous (about 6000) islands of which only 227 are inhabited. In the mainland, the Pindus mountain massif runs from north to south and divides Greece into the western part which receives high amounts of rainfall (humid climate) and the eastern part which receives reduced rainfall (semi-arid climate). Another series of high mountains runs along the northern borders of the country that mark the limits of the Mediterranean climate to the Balkan Peninsula. An evolution from wet to dry climate is also observed from the north to the south of the mainland. In the islands, mainly located to the south-eastern part of Greece, the driest bioclimate of the whole country is recorded (Mavrommatis, 1980). At the local scale, there are pronounced climatic differences over very short distances due to factors such as slope, aspect, distance from the sea, steepness and parent rock type. However, the mean air temperature of the coldest month (January) reaches 12 °C in the island of Crete and 0.8 °C at the city of Florina in northwest Macedonia while the mean annual rainfall varies from 300 mm (in Cyclades Islands) to 1253 mm (at the city of Ioannina in Epirus) (Tan and Iatrou, 2001).

As result of the variable climate and relief, livestock displacement has been a standard practice over the centuries. Before World War I, flocks were moving over long distances all over the Balkan Peninsula within the Ottoman Empire, because they were no national borders. After the war, however, when Ottoman Empire was dissolved and the borders of the present-day Greece were established, flock movement was restricted within the national territory. Since then transhumance is mainly done between the coastal areas and the Pindus mountain range or between lowlands and highlands in several parts of the country. According to Laga *et al.* (2005a), the longest transhumance distance in central Greece is 270 km. Unlike Spain and Italy, though, Greece does not have a network of fixed corridors for transhumance, apparently because they were destroyed when the present-day nations were formed in the Balkan Peninsula in the beginning of the 20th century. Another reason is the conversion of large parts of these corridors to private arable lands in order to accommodate the needs of the refugees from Turkey, which arrived in Greece in the aftermath of the World War I.

In contrast to Spain and Italy, Greece has several ethnic groups related with flock mobility with the most notable being “Sarakatsani” and “Vlachi”, who developed a

special culture on nomadism and transhumance (Ispikoudis *et al.*, 2004). As result of socioeconomic changes, however, sheep and goat flocks practising transhumance have been drastically reduced over the last 30-40 years. In 1961, for example, 15% of the total number of sheep and 13% of goats practised transhumance, while in 2001 these percentages were reduced to 7% and 5% respectively for the two kinds of animals (NSSG, 1963-2005). In the meantime, the traditional movement of animals on foot that took more than one month to go from the winter to summer pastures was replaced by transportation with trains and more recently by specialized vehicles. In the past, not only the shepherd but all his family was following animals in the mountains, where special summer schools for the children were organized in order to complete their education that was interrupted by the departure of the shepherd's family before the end of the school year in the middle of June. Gradually, this custom was discontinued and shepherds are currently the only ones following the animals in the summer pastures, while their families stay back to the villages (Tsakanika and Ispikoudis, 2006).

Officially, grazing lands occupy about 40% of the whole Greece. These are predominantly (75%) public forest lands which are used in a communal way within the territory of each village community (Papanastasis, 2009). In reality, however, livestock are grazing in a much larger area, which also includes a large part of forests thus increasing the total area affected by pastoralism to about 65% of the whole country. As a result, landscapes and biodiversity of the Greek territory are largely related to livestock husbandry. In the past, specialized indigenous breeds of sheep and goats as well as horses, mules and donkeys were using grazing lands characterized by their small size and their adaptation to the local environmental conditions. Nowadays, most of these breeds have been crossed with more productive ones thus losing the traditional high animal diversity (Sarlis, 1998; Zervas, 1998; Hatziminaoglou, 2006).

As far as plant diversity is concerned, Greece has more than 5500 plant species (more than 7000 taxa), of which 780 (more than 1270 taxa) are endemics, thus being one of the richest regions in Europe and in Mediterranean in relation to its size (Strid and Tan, 1997; Tan and Iatrou, 2001). On the other hand, out of the 218 habitat types of European interest recorded in the EU habitat Directive, Greece harbours 109 (Dafis *et al.*, 2001). The grassland habitat type with the highest amount of plant associations is *Thero-Brachypodieta* (Kakouros, 2003) which includes the annual plant communities (Mucina, 1997; Dafis *et al.*, 1997, 2001). Another 17 grassland habitat types with 137 plant associations have been also recorded; eight of them are grassland habitats of high priority (Dafis *et al.*, 2001; Kakouros, 2003). The most common grassland phytosociological classes are *Junceteta trifidi*, *Festuco-Brometeta* (Quezel, 1964, 1967; Petermann, 1999; Dafis *et al.*, 2001; Fotiadis *et al.*, 2006) and the mesophile and wet heaths of the class *Molinio-Arrhenatheretea* (Dafis *et al.*, 2001; 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 (Quezel, 1964, 1967; Dimopoulos, 1993; Bergmeier, 2002b; Karetsos, 2002) and those of the xerothermic lowland areas with dwarf, dry tolerant shrubs (phrygana of *Cisto-Micromerietea*) (Dimopoulos, 1993; Phitos *et al.*, 1995; Gouvas, 2001; Bergmeier, 2002b), where the plant diversity is very high (almost 100-120 species per 200 m²) (Phitos *et al.*, 1995; Tan and Iatrou, 2001). The relationship between vegetation diversity and grazing management is further discussed in Panitsa (1997), Alados *et al.* (2004), Vrahnakis *et al.* (2005c), Theodoridis and Koukoura (2006), Papadimitriou *et al.* (2006), Tziialla (2006), Vrahnakis (2008) and Ganatsou *et al.* (2008).

The single Mediterranean biogeographical region of Greece has been divided into three zones: Mediterranean Mountains, North and South (Metzger *et al.*, 2005). Within these three zones, four geographical sectors were identified (Table 3): Mediterranean Mountains with three sub-sectors (North Pindus, South Pindus and North Peloponnesus), Mediterranean North with two sub-sectors (Thrace and Central Macedonia), Mediterranean South (Mainland) with three sub-sectors (Western Epirus, Eastern Thessaly and South-eastern Peloponnesus) and Mediterranean South (Islands) with two sub-sectors (Central Crete and Dodecannisa).

The Mediterranean mountains sector

This sector includes the Pindus mountain range that runs the mainland from the Albanian borders in the north to Sterea Ellada in the south as well as the high mountains of northern Peloponnesus which follow as an extension of the Pindus range to the south. The whole sector constitutes the backbone of Greece and the area where the majority of productive forests are found. Soils are derived mainly from the bedrocks of flysch and hard limestone (Nakos, 1977). Climate ranges from attenuated meso-Mediterranean to sub-Mediterranean and axeric temperate with 0-75 biologically dry days (Mavrommatis, 1980). This means that biological activity occurs only during summer while the winter period is too cold for the plants to grow.

TABLE 3

Main Greek LSGS by biogeographical region.

Características de los principales sistemas pastorales griegos según regiones biogeográficas.

Biogeographical region and code	^a Regional location	^b Main production objectives	^c Presence of indigenous breeds	^d Actual area (km ²)	^e Main vegetation types
1. Mediterranean Mountains					
1a	North Pindus	DS, MS, DG, MG, MC, BG,	S, G, C, WG	1900	9110, 9130, 9140, 91E0, 9250, 9260, 9270, 9280, 92A0, 92C0, 9530, 9540
1b	South Pindus	DS, MS, DG, MG, MC, BG	S, G, C	4200	91F0, 92A0, 92C0, 92D0, 9280, 9320, 9340, 9350, 9530, 9540, 9560
1c	North Peloponnesus	DS, MS, DG, MG	S, G	1950	9280, 92A0, 92C0, 92D0, 9340, 9350, 9530, 9540, 9560
2. Mediterranean North					
2a	Thrace	DS, MS, DG, MG, MC, DC	S, G	2200	9110, 9130, 91B0, 91E0, 91F0, 9270, 9280, 92A0, 92D0, 9410, 9530, 9540
2b	Central Macedonia	DG, MG, DS, MS, MC, DC	S, G, C	9100	9110, 9120, 9130, 91E0, 91F0, 9260, 9270, 9280, 92A0, 92C0, 92D0, 9310, 9340, 9530, 9540, 9580
3. Mediterranean South (mainland)					
3a	Western Epirus	DS, MS, DG, DS, MC	S,G	1600	9280, 92A0, 92C0, 92D0, 9340, 9350, 9540
3b	Eastern Thessaly	DS, MS, DG, MG, MC, DC	S, G, C	3200	9110, 9120, 9130, 9170, 91B0, 9260, 9270, 9280, 92A0, 92C0, 92D0, 9320, 9340, 9350, 9530, 9560
3c	SE Peloponnesus	DG, MG, DS, MS	S,G	2800	9260, 9280, 92D0, 92C0, 9320, 9530, 9540, 9560
4. Mediterranean South (islands)					
4a	Central Crete	DS, MS, DG, MG	S, G	1850	9290, 92A0, 92C0, 92D0, 9310, 9320, 9350, 9370, 9540
4b	Dodecannisa	MG, MS	S, G, FD	1250	92C0, 92D0, 9290, 9350, 9540

^a Main geographical territories of presence.^b MC: Meat cattle; DC: Dairy Cattle; DS: Dairy Sheep; MS: Meat Sheep; DG: Dairy Goats; MG: Meat Goats; BG: Big Game.^c Presence of indigenous breeds of Cattle (C), Sheep (S), Goats (G), Wild Goat (WG), Fallow Deer (FD).^d Area is approximate; potential area can be larger.^e Main types of natural vegetation referred to habitat codes of the Directive 92/43 (EC, 2003).

For livestock husbandry, the importance of the sector lies on the grasslands grown in the subalpine zone, above the timberline, which are used as summer pastures by flocks coming from both the western and eastern to the mountain range lowlands. In the past, these grasslands were the centre of summer grazing activity with animals and shepherds with their families living there for more than four months each year. Nowadays, most of these grasslands are underutilized or abandoned due to the sharp reduction of transhumance (Laga *et al.*, 2005a). As a result, biodiversity of grasslands has been deteriorated. Unpalatable grasses such as *Nardus stricta*, *Festuca varia* and *Calamagrostis arundinacea* have grown up and several “weeds” such as *Pteridium aquilinum* have expanded. In addition, several woody species such as *Vaccinium myrtillus*, *Rosa canina* and *Juniperus communis* ssp. *nana* started to invade grasslands followed by tree species of the nearby forests (such as *Pinus heldreichii* and *P. nigra* spp. *nigra* var. *caramanica*).

Main forest vegetation types in this sector are: (i) *Verbasco glabrati-Quercetum frainetto* and *Trifolium ochroleucon-Quercus frainetto* community which include forests of *Quercus frainetto* (Gamisans and Hebrard, 1979; Karetso, 2002; Bergmeier and Dimopoulos, 2008); (ii) *Dryopterido pallidae-Ostryetum carpinifoliae*, *Tilio tomentosae-Castanetum* and *Quercu-Castanetum* which includes mixed and pure forests of broadleaved species such as *Ostrya carpinifolia*, *Tilia tomentosa* and *Castanea sativa* (Bergmeier and Dimopoulos, 2008); (iii) beech forests classified in *Geranium versicolor-Urtica dioica-Fagus sylvatica* comm. of humid mesotrophic habitats, *Orthilio secundae-Fagetum* of acidic habitats and *Geranio striati-Fagetum* and *Rubus canescens-Fagus sylvatica* comm. of moderately warm and dry habitats; and (iv) coniferous forests of *Pinus nigra* ssp. *nigra* var. *caramanica* (*Pino nigrae-Ciceretum graeci*, *Pino nigrae-Crataegetum pycnolobae*, *Trifolio alpestri-Pinetum pallasianae*, *Stachelino-Pinetum pallasianae*), *Abies* spp. (*Abieti cephalonicae-Helictotrichetum convoluti*, *Abieti cephalonicae-Lilietum chalcidonicum*, *Quercus ilex-Abies cephalonica*, *Abies xborisii-regis-Trifolium speciosum* and many other *Abies xborisii-regis* communities) (Quezel 1967; Barbero and Quezel, 1976; Gamisans and Hebrard, 1979; Dimopoulos, 1993; Bergmeier and Dimopoulos, 2001; Karetso, 2002).

Among the three sub-sectors of the Mediterranean Mountains, North Pindus (1a) involves three prefectures (Kastoria, Grevena and Ioannina), which amount to an area of about 9000 km² (NSSG, 1995). It includes three high mountains, i.e. Grammos, Smolikas and Tymphi, with an average peak altitude of 2500 m. Main vegetation types related to livestock husbandry in this sub-sector are the subalpine grasslands, where several tree and shrub species and subspecies are also found (e.g. *Pinus heldreichii*, *P. nigra* ssp. *nigra* var. *caramanica*, *Juniperus foetidissima*, *J. communis* ssp. *nana*, *Vaccinium myrtillus*, *Rubus* sp. and *Rosa* sp.) and are classified in *Juncetea trifidi* with major vegetation types

of *Nardus stricta* and *Trifolium parnasi*. Also, vegetation types of *Daphno-Festucetea* dominated by species such as *Daphne oleoides*, *Festuca varia*, *Koeleria lobata*, *Poa cenisia*, *P. thessala*, *Stipa pennata*, *Thymus* spp., etc. and of *Molinio-Arrhenatheretea* dominated by species such as *Geum coccineum*, *Deschampsia flexuosa*, etc. are found in this area (Quezel, 1967; Horvat *et al.*, 1974; Dafis *et al.*, 1997, 2001).

Two national parks are included in this sub-sector: Vikos-Aoos and Pindus. Vikos-Aoos national park amounts to an area of about 122 km², covered by deciduous and coniferous forests as well as shrublands while grasslands of *Juncetea trifidi*, *Molinio-Arrhenatheretea* and *Daphno-Festucetea* (Dafis *et al.*, 2001) are found in the subalpine zone (Hanlidou and Kokkini, 1997). The park has a high biodiversity. Flora contains several Greek and Balkan endemics and rare taxa such as *Valeriana crinii* ssp. *epirotta*, *Prometheum tympaemum*, *Centaurea epirotta* and *Ramonda serbica* (Greuter *et al.*, 1986; Tutin *et al.*, 1976; Hanlidou and Kokkini, 1997). Fauna includes brown bear (*Ursus arctos*), wolf (*Canis lupus*), otter (*Lutra lutra*), wild goat (*Rupicapra rupicapra*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) (Papageorgiou, 1990; Dafis *et al.*, 1997; Papaioannou, 2005). Pindus national park occupies an area of about 35 km² which is covered by dense forests of coniferous species (*Pinus nigra* ssp. *nigra* var. *caramanica*, *P. leucodermis*) as well as beech (*Fagus sylvatica*). Flora contains several rare or Greek endemic taxa such as *Silene radicata* ssp. *rechingeri*, *Leptoplax emarginata*, *Alyssum heldreichii* and *Peucedanum stridii* (Strid, 1986).

Rangelands of the sub-sector amount to about 1900 km² (NSSG, 1995) corresponding to 21% of the whole area and have a mean stocking rate of about 0.26 LU/ha (ASG, 2003). They are public forest lands communally used by shepherds within each village territory of the sub-sector. The main livestock species using rangelands are sheep while goats are of secondary importance and cattle relatively limited.

The North Pindus LSGS is one of the most traditional in Greece. Almost all the animals belong to the ethnic groups of Sarakatsani and Vlachi, who have been practising pastoralism in the area for centuries. However, very few of the old practices are still followed (Ispikoudis *et al.*, 2004), while there is a constant reduction of the number of small ruminants involved in transhumance (Laga *et al.*, 2005b). The reduced grazing pressure has resulted in significant deterioration of biodiversity with the most notable development being the increase of unpalatable species and shrub and tree encroachment. In the subalpine grasslands of the Grammos mountain, for example, Iovi *et al.* (2003) found a high species diversity but this diversity was higher in the heavily than in the lightly grazed parts of the mountain. Theodoridis and Koukoura (2006) also found that intensive grazing by livestock in the subalpine grasslands of the sector favours species diversity, especially of perennial grasses and forbs.

Sheep belong to local breeds (mountainous type) and is raised for milk and meat (lambs). Milk yields range from 80 to 110 kg/head and the carcass weight of lambs at sale from 8 to 10 kg. Milking is done manually. Flocks are relatively large (about 400 heads), pure or mixed with a few goats (Laga *et al.*, 2005b). Goats also belong to the local non-improved breeds and are bred for the same purposes as sheep. Milk yields are greater than sheep (100-130 kg/head) but kid carcass weight at sale is smaller (5-7 kg). In contrast, flocks are larger than in sheep (more than 500 heads) and besides grasslands, they also graze in the forests. Sometimes, goats are also fed with branches of forest trees (Yannakopoulos and Papanastasis, 1987). The milk produced by sheep and goats is used to produce several dairy products, mainly pheta cheese, but also other kinds of soft and hard cheeses (Laga *et al.*, 2005b). All these products of the sub-sector as well as lambs and kids are famous in the market.

Grazing is done during the summer period for about 4 months. In dry summers, flocks are displaced in other areas of the same sector (Laga *et al.*, 2005b). In the past, no additional feed was given to the animals besides the forage from rangelands. However, since the European subsidies started in 1980s and, especially, in 1990s, most shepherds feed their animals with small quantities of grain (e.g. 300-400 g of maize per day per head of sheep or goat) during the whole summer. Cattle mainly graze in the forests than in the subalpine grasslands. In the winter period, all animals are moved to the lowlands. Even there, however, forage production in rangelands is seasonal forcing farmers to become dependent on conserved forage feeds and more reliant on supplemental feeding from September to March-April (Zervas and Samouchos, 2005). Shepherds permanently herd all kind of animals.

The South Pindus sub-sector (**1b**) of the Mediterranean mountains involves four prefectures (Evrytania, Fthiotida, Fokida and Voiotia) which amount to an area of about 9500 km² (NSSG, 1995). It includes four high mountains, i.e. Vardousia, Giona, Oiti and Parnassus, with an average peak altitude of 2400 m. Main vegetation types related to livestock husbandry are those of calcareous mountains, above timberline, where plant communities of (i) *Daphno-Festucetea*, dominated by *Daphne oleoides*, *Astragalus angustifolius*, *Anthoxanthum odoratum*, *Stipa pennata*, *Dactylis glomerata*, *Eryngium* spp., *Festuca* spp. and of (ii) *Juncetea trifidi*, dominated by *Nardus stricta* are found (Quezel, 1964; Dafis *et al.*, 1997; 2001; Karetzos, 2002). Vrahnakis *et al.* (2005c) have found that grasslands sustain the highest α -diversity compared with adjacent shrublands dominated by *Juniperus* species as well as open fir (*Abies cephalonica* and *A. xborisii-regis*) forests.

Two national parks are also included in this sub-sector: Oiti and Parnassus. Oiti national park has an area of 42 km², which is covered by an *Abies* spp. (*A. cephalonica* and *A. xborisii-regis*) forest as well as deciduous forests and shrublands. Among the

most interesting rare and Greek or local endemic species are: *Laserpitium pseudomeum*, *Trinia frigida*, *Achillea umbellata*, *Taraxacum gionense*, *Veronica oetea*, *Alyssum gustavssonii* and many others (Karetzos, 2002). Fauna is also rich and includes roe deer (*Capreolus capreolus*) and wolf (*Canis lupus*) (Papageorgiou, 1990). Parnassus national park has an area of 35 km² which is covered by a pure *Abies* spp. (*A. cephalonica* and *A. xborisii-regis*) forest but has high plant diversity with the most characteristic Greek and local endemic species being *Paeonia parnassica*, *Satureja parnassica*, *Beta nana*, *Erysimum parnassii*, *Astragalus appolineus* and *Trifolium parnassi* (Phitos *et al.*, 1995; Tan and Iatrou, 2001). Fauna is also very rich and includes fox (*Vulpes vulpes*), badger (*Meles meles*), hare (*Lepus europeus*) and squirrel (*Sciurus vulgaris*) (Papageorgiou, 1990; Dafis *et al.*, 1997).

Rangelands of the sub-sector amount to about 4200 km² (NSSG, 1995) corresponding to 44% of the whole area and have a mean stocking rate of about 0.35 LU/ha (ASG, 2003). They are also public forestlands communally grazed by livestock. Sheep are again the main livestock species using rangelands but goats are more important than in the North Pindus sub-sector while cattle are again relatively limited. Although vertical transhumance is also practised in this sub-sector, it does not involve such long distances as in North Pindus. During the winter period, animals are kept in the lowlands and on the foothills while in the summer they are moved to the high and subalpine zones.

Flocks are pure or mixed and shepherded the whole year round. Sheep and goats are raised for milk and meat (Ziogas *et al.*, 2003) and cattle for meat.

The North Peloponnesus sub-sector (**1c**) of the Mediterranean mountains, finally, involves the prefectures of Achaia and Korinthos, which amount to an area of about 5500 km² (NSSG, 1995). It includes three high mountains, i.e. Erymanthos, Chelmos and Killini, with an average peak altitude of 2300 m. The vegetation related to livestock husbandry is mostly mountainous of *Daphno-Festucetea* (*Stipo-Morinion*, *Eryngio-Bromion*, *Astragalo-Seslerion*) with many spiny species adapted to grazing (e.g. *Astracantha thracica*, *Astragalus angustifolius*) (Quezel, 1964; Dimopoulos, 1993). The percentage of Greek endemic species such as *Marrubium pilcheri*, *Crataegus pycnoloba* and *Cicer graecum* in this area is very high (19.7% on the Killini mountain and 17.1% on the Chelmos mountain) (Tan and Iatrou, 2001).

Rangelands of the sub-sector amount to 1950 km² (NSSG, 1995), corresponding to 35% of the whole area and have a mean stocking rate of 0.75 LU/ha (ASG, 2003). They are private or mostly public forest lands communally used by livestock. Sheep are the main livestock species followed by goats while cattle are very limited. Vertical transhumance is not very common, especially for sheep. The latter use the rangelands the whole year round but, in the summer, they also graze on agricultural areas after crop

harvesting. During the winter period, they are fed with hay and concentrates for at least 5 months (Zervas *et al.*, 1996).

Flocks of sheep are either pure or mixed with a small proportion of goats and they are permanently shepherded. In the mountain area of Feneos (Korinthos), the average flock size for sheep is 88 animals of which 50% are of the local breed and the rest are cross-breeds with other, more productive, while the average milk production is 76 kg/head. Grazing lands cover 66% of their energetic requirements on an annual basis (Zervas *et al.*, 1996).

The Mediterranean north sector

This sector includes the lowlands and highlands of the largest part of Northern Greece (Macedonia and Thrace). Soils are derived mainly from metamorphic rocks (Nakos, 1977). Climate ranges from accentuated meso-Mediterranean to sub-mediterranean with 40-100 biologically dry days (Mavrommatis, 1980). Plant growth mainly occurs in the spring as well as in autumn, which means that there is a winter period of 3-5 months of slow or no growth and a dry summer period of almost 2 months (Papanastasis, 1982).

For livestock husbandry, the importance lies not only on grasslands but also on shrublands dominated by deciduous (e.g. *Carpinus orientalis*, *Fraxinus ornus*, *Cornus mas*, etc.) as well as evergreen species (maquis, garrigues). For this reason, goats are as numerous and important as sheep. In addition, due to rolling topography and especially due to the large and fertile plains where hay and grain are produced, the sector is also important for cattle including beef cattle that also use rangelands. Grasslands located in the low elevation zone (up to 600 m) are dominated by the perennial C₄ grasses *Chrysopogon gryllus* and *Dichanthium ischaemum*; of the middle elevation zone (600-800 m) by a mixture of C₄ and C₃ grasses, the latter including *Koeleria cristata* as well as species of *Festuca* and *Phleum* and the high elevation zone including the subalpine one dominated by *Brachypodium pinnatum*, *Bromus cappadocicus* ssp. *lacmonicus*, *Festuca* spp. and *Anthoxanthum odoratum* (Papanastasis, 1981). Under heavy grazing pressure, perennial grasses are reduced in favour of annuals, particularly in the low elevation zone. They include *Hordeum murinum*, *Vulpia myuros*, *Medicago minima*, *Trifolium nigrescens*, *Anthemis auriculata* and *Plantago lagopus* (Koukoura *et al.*, 1998; Tsiouvaras *et al.*, 1998). Besides being rich in plant species (Papadimitriou *et al.*, 2004), grasslands are also rich in fauna. Stais and Pyrovetsi (2006) found high bird abundance in grazed grasslands, while Ispikoudis *et al.* (2006) state that livestock activities, especially animal sheds, attract a high number of passerine birds that also prefer open plant communities such as grasslands. In shrublands, the more open they are the more biomass available to livestock, especially to goats, they produce (Platis and Papanastasis, 2003). In addition, open shrublands have higher α -plant diversity (Vrahnakis *et al.*,

2005b) and higher numbers of avifauna than the denser ones (Papoulia *et al.*, 2006). Furthermore, grazing activities around animal sheds influences vegetation by creating a gradient from very open to dense shrubland communities as we move away from them (Papanastasis *et al.*, 2009).

Main forest vegetation types in this sector are: (i) *Quercus coccifera-Phillyrea latifolia* community and *Quercus coccifera-Juniperus oxycedrus* community which include the evergreen shrublands of *Quercus coccifera* (Theodoropoulos, 1991; Fotiadis, 2004; Fotiadis *et al.*, 2006); (ii) *Phillyreo-Carpinetum orientalis* and *Rhagadiolo stellati-Paliuretum spina-christii* which includes shrublands and forests of mixed evergreen and broadleaved species (*Phillyrea latifolia*, *Quercus coccifera*, *Paliurus spina-christi*, *Quercus pubescens*, *Carpinus orientalis*) (Fotiadis, 2004; Bergmeier and Dimopoulos, 2008); (iii) *Symphyto ottomani-Quercetum frainetto* and *Digitali viridiflorae-Quercetum frainetto* which includes forests of *Quercus frainetto* (Gamisans and Hebrard, 1980; Bergmeier and Dimopoulos, 2008); (iv) *Genisto carinalis-Quercetum petraeae* and *Trifolio balcanico-Quercetum medwediewii* which includes forests of *Quercus petraea* ssp. *medwediewii* (Fotiadis, 2004; Bergmeier and Dimopoulos, 2008) and (v) *Tilio tomentosae-Castanetum* and *Quercu-Castanetum* which includes mixed and pure forests of *Tilia tomentosa* and of *Castanea sativa* (Petermann, 1999; Bergmeier and Dimopoulos, 2008).

Among the two sub-sectors of the Mediterranean North, Thrace (2a) involves the prefecture of Evros, Rodopi and Xanthi and amounts to an area of about 8600 km² (NSSG, 1995). Its altitude ranges from the sea level up to 1800 m, the latter corresponding to the peak of the Rodopi mountain range. The sub-sector mainly includes open forests of *Quercus frainetto*, *Q. pubescens*, *Pinus nigra* ssp. *nigra* var. *caramanica* and *Quercus ithaburensis* ssp. *macrolepis* as well as *Q. coccifera* shrublands of *Quercetalia pubescentis* (Dafis *et al.*, 2001). Some of these forests and shrublands are open thus allowing a rich understory with plant species (almost 60 species/ 150 m²) (Pantera *et al.*, 2001). Grasslands are restricted between forest and cultivated lands and represented by the classes *Festuco-Brometea* and *Thero-Brachypodietea*. The presence of the alliance *Molinio-Holoschoenion* and of the classes *Thero-Salicornietea* and *Juncetalia maritimae*, used mainly by cattle and sheep, should be also mentioned (Horvat *et al.*, 1974; Dafis *et al.*, 1997, 2001; Stroh, 2002). Flora contains several rare or endemic taxa such as *Minuartia greuteriana*, *Salix xanthicola* and *Eriolobus trilobatus* (Phitos *et al.*, 1995). The sub-sector includes the national park of Dadia-Lefkimi-Souffi, which covers an area of 432 km². Grasslands and open forest stands of the park is characterized by a high species richness (Korakis and Gerasimidis, 2006). The park has a long history of livestock grazing closely associated with plant and animal diversity.

Rangelands of the sub-sector amount to about 2200 km² (NSSG, 1995) or 26% of the whole area and have a mean stocking rate of 0.89 LU/ha (ASG, 2003). They are public forestlands communally grazed by livestock. Sheep, goats and cattle are of equal importance in this sub-sector. These animals graze in rangelands, mainly in spring and autumn. In the winter period, they are kept in the barn and fed with hay and concentrates; sheep and goats may also use temporary pastures sown with winter cereals (e.g. barley and wheat). One ethnic group of farmers (Pomaki) still use oak foliage to feed their animals, mainly goats, in the winter period after shredding the oak branches at the end of summer and conserving them for the winter. In the summer, they graze in the stubble of the harvested crops in the plains or move to rangelands and forests at higher altitudes, usually within the village territory. Grazing intensity is not uniform throughout the sub-sector. In several areas, particularly those around villages or animal concentration points (watering points, sheds) overgrazing is applied.

Sheep and goat flocks are pure or mixed (sheep with a few goats) and belong to local or semi-improved breeds of the plain type. In the nearby prefecture of Drama, Katanos *et al.* (2005) have found that the majority of goat flocks have more than 200 heads, consist of the native Greek breed and produce about 150 kg of milk per doe and day. Both sheep and goats are raised for milk and meat while wool is non-important. Dairy products are several cheeses with most important being the pheta cheese as well as yogurt and butter. Cattle grazing in rangelands are raised only for meat.

The Central Macedonia sub-sector (**2b**) involves three prefectures (Kilkis, Thessaloniki and Chalkidiki) with an area of about 9100 km² (NSSG, 1995). It extends from the sea level up to 1200 m. Major mountain ranges in this sub-sector are Kroussia, Vertiskos and Holomontas. Vegetation types related to livestock husbandry are mainly kermes oak (*Quercus coccifera*) shrublands (*Phillyrea latifolia-Quercus coccifera* comm. and *Juniperus oxycedrus-Quercus coccifera* comm.) that support high floristic diversity; almost 66 species per 70 m², with more than five *Trifolium* species per 100 m² (Fotiadis *et al.*, 2001); most common grasses are *Dactylis glomerata* and *Stipa bromoides*. Grassland vegetation types such as *Festuco-Brometea* and *Thero-Brachypodietea* are commonly found in openings and in field edges (Horvat *et al.*, 1974; Dafis *et al.*, 1997, 2001).

Rangelands of the sub-sector amount to 2400 km² (NSSG, 1995) or 26% of the whole area and have a mean stocking rate of about 1.10 LU/ha (ASG, 2003). This is a high stocking rate compared with their grazing capacity (Papanastasis, 1977). For this reason, several of them are very degraded or even desertified (Evangelou *et al.*, 2005; Roeder *et al.*, 2007; Lorent *et al.*, 2008). Rangelands are largely public forest lands communally used by livestock. The dominant livestock species are goats followed by sheep and then by cattle. Sheep and cattle are grazing in grasslands and forests, while goats in the extensive shrublands of evergreen species (maquis and garrigues). Grazing

is done in the spring and autumn. In the winter period, animals are fed with hay and concentrate or graze in temporary pastures with cereals (Yiakoulaki *et al.*, 2003). In the summer, they graze in the stubble of the harvested crops or move to higher elevations (Yiakoulaki *et al.*, 2003; Yiakoulaki and Papanastasis, 2006). In coastal areas, where evergreen shrublands are usually grown, goats graze during the winter period as well (Vrahnakis *et al.*, 2005a). In a study carried out in maquis-type shrublands of Sithonia and Chalkidiki (Alados *et al.* 2004) found increased plant diversity in moderately grazed as compared to lightly and heavily grazed areas.

Sheep and goat flocks are pure or mixed (sheep with a few goats) and they are permanently herded (Yiakoulaki *et al.*, 2003). They belong to semi-improved local breeds of the plain type and are raised for milk and meat, while wool is non-important Kitsopanidis *et al.*, 2009). Milk is used for several dairy products such as, “pheta” cheese, kasseri and yogurt. Grazing cattle are also herded and raised for meat.

The Mediterranean south (mainland) sector

This sector includes lowlands in Epirus, Thessaly and Peloponnesus. Geology is variable and includes hard limestone, metamorphic and igneous rocks (Nakos, 1977). Climate ranges from attenuated thermo-Mediterranean to accentuated meso-Mediterranean with 100-125 biologically dry days (Mavrommatis, 1980). Plant growth occurs mainly in the winter period, from October to mid-May, while the summer period is long and dry (Platis *et al.*, 2006).

For livestock husbandry, the importance lies not only on grasslands but also on garrigues, which include kermes oak (*Quercus coccifera*) shrublands grown on calcareous soils as well as phrygana of *Phlomis fruticosa* and *Salvia fruticosa*. These latter species, however, are unpalatable to sheep and to some extent to goats as well. For this reason, shepherds are traditionally using pastoral wildfires to control the woody species and favour the establishment of palatable herbaceous species, a practice that together with overgrazing has led to degradation of these particular rangelands (Papanastasis, 1976). The sector is important for sheep and goats that are using rangelands during the winter period while in the summer they are moving to the summer ranges of the Mediterranean mountains sector. Cattle are of limited importance in this sector.

Grasslands consist of a high variety of herbaceous species. The most important of them are: *Hyparrhenia hirta*, *Dactylis glomerata*, *Anthoxanthum odoratum*, *Aegilops neglecta*, *Avena barbata*, *Medicago lupulina*, *Trifolium arvense*, *T. subterraneum*, *Anthemis arvensis* and *Thymus sibthorpii* (Papanastasis and Gogos, 1983; Platis *et al.*, 2006). Hadjigeorgiou and Karalazos (2005) found that moderate grazing of such grasslands located at the low elevation zone of central Greece results in higher species diversity than low grazing pressure. Besides being rich in plant species, they also host

a significantly higher number of breeding bird species than arable lands (Sfougaris and Tsiligiannis, 2006). Kermes oak garrigues have also a large variety of herbaceous species, annual and perennial; a common perennial grass is *Brachypodium retusum*. Phrygana, finally, are open plant communities with a large variety of herbaceous species grown among the phryganic species, annual and perennial. Some of the most important of them are *Dasypyrum villosum*, *Bromus sterilis*, *Cynosurus echinatus*, *Dactylis glomerata*, *Trifolium nigrescens*, *T. campestre* and *Sanguisorba minor* (Papanastasis and Gogos, 1983; Kandreliis, 2001).

Grazing management of this sector is characterized by the combined use of pastoral wildfires and overgrazing. The normal fire cycle is 3-5 years (Papanastasis, 1980). An increase of the number of animals as a result to EU subsidies in the 1980s and 1990s together with an increased demand for higher milk production has led shepherds to shortening the fire cycle in the last few decades in order to ensure more and better food to their animals. However, the increase of wildfire frequency coupled with overgrazing has seriously deteriorated rangelands (Papanastasis, 1978).

Main forest vegetation types in this sector are: (i) *Arbuto andrachne-Quercetum ilicis*, *Orno-Quercetum ilicis*, *Quercus coccifera-Phyllirea latifolia* comm. and *Quercus coccifera-Juniperus oxycedrus* comm., which includes the major evergreen shrublands (maquis and garrigues) (Barbero and Quezel, 1976; Raus, 1980); (ii) *Phillyreo-Carpinetum orientalis*, which includes shrublands and forests of mixed evergreen and broadleaved species (*Phillyrea latifolia*, *Quercus pubescens*, *Carpinus orientalis*) (Bergmeier and Dimopoulos, 2008); (iii) *Verbasco glabrati-Quercetum frainetto*, *Huetio-Quercetum frainetto* and *Geranio asphodeloidis-Quercetum frainetto*, which includes forests of *Quercus frainetto* in the west, east and south part of the sector respectively (Barbero and Quezel, 1976; Raus, 1980; Bergmeier and Dimopoulos, 2008); (iv) *Genisto carinalis-Quercetum petraeae*, which includes forests of *Quercus petraea* ssp. *medwediewii* (Bergmeier and Dimopoulos, 2008); (v) *Dryopterido pallidae-Ostryetum carpinifoliae*, *Tilio tomentosae-Castanetum*, *Querco-Castanetum* and *Cytiso villosi-Castanetum*, which includes mixed and pure forests of broadleaved species such as *Ostrya carpinifolia*, *Tilia tomentosa*, *Castanea sativa* (Barbero and Quezel, 1976; Raus, 1980; Bergmeier, 1990; Bergmeier and Dimopoulos, 2008); and (vi) *Abietion cephalonicae* or plant communities of *Pino-Juniperetea* which includes coniferous forests of *Abies* spp. and *Pinus nigra* ssp. *nigra* var. *pallasiana* (Brullo et al., 2001; Bergmeier, 2002a).

Among the three sub-sectors of the Mediterranean South in the mainland, Western Epirus (3a) involves the prefectures of Thesprotia and Preveza amounting to an area of about 2500 km²(NSSG,1995). It represents a coastal area ranging from the sea level up to 800 m altitude. Major vegetation types related to livestock husbandry are

the phryganic vegetation with *Phlomis fruticosa* and *Cistus* spp. and garrigues with *Quercus coccifera*, also found in the understory of open forests (*Quercus ithaburensis* ssp. *macrolepis*, *Q. pubescens* etc.). It is worth mention the presence of the habitat types *Thero-Salicornietea* (annual plant communities of salt marshes) and *Arthrocnemetalia fruticosae* (mediterranean halophilous scrubs) (Dafis *et al.*, 1997, 2001). Flora contains several endemic taxa such as *Petrorhagia glumacea*, *Erysimum cephalonicum*, *Galanthus reginae-olgae* ssp. *vernalis* and *Ophrys spruneri* ssp. *spruneri* (Tan and Iatrou, 2001).

Rangelands of the sub-sector amount to about 1600 km² (NSSG, 1995) or 64% of the whole area and have a mean stocking rate of 0.90 LU/ha (ASG, 2003). The ownership status of these rangelands is not clear; this is why there are a lot of conflicts between shepherds and the state (Papanastasis, 1978). Sheep are the dominant livestock species followed by goats while cattle are of limited importance. Grazing starts in October to November when animals arrive from the summer pastures of the Pindus Mountain and lasts until the middle of May, when they again depart. Wildfires are set by shepherds when phryganic species get too dense and during hot and windy summer days. Once the new growth starts after the first autumn rains, animals are put into the burned areas in order to make use of the young and nutritious new growth (Papanastasis, 1976).

Flocks of sheep and goats are pure or mixed (sheep with a few goats) and belong to local breeds. They are raised for milk and meat, while wool is non-important.

Eastern Thessaly sub-sector (**3b**) involves the prefectures of Larissa and Magnesia and amounts to an area of about 8000 km² (NSSG, 1995). It extends from the sea level up to 800 m altitude. Major vegetation types related to livestock husbandry are phryganic vegetation with *Cistus* spp. (*Cistus salviifolius* comm., *Thymus sibthorpii-Cistus creticus* comm.), *Sarcopoterium spinosum* (*Sarcopoterium spinosum* comm.), *Phlomis fruticosa* (*Allio pulchellii-Phlometum fruticosae*) and *Coridothymus capitatus* (*Corydothymion*) (Raus, 1979, 1980). Annual plant communities of *Thero-Brachypodietaea*, rupicolous calcareous or basophile grasslands of the *Alyso-Sedion albi* and tall humid herb grasslands of *Molinio-Holoschoenion* (Dafis *et al.*, 1997, 2001) are found between forests, shrublands and cultivated lands. Flora is of high diversity (70-80 taxa per 100-150 m²; Raus, 1979) and contains several rare or Greek endemic taxa such as *Campanula incurva*, *Cerastium candidissimum*, *Silene linoides*, *Erysimum graecum*, *Nepeta argolica* ssp. *malacotrichos* (Phitos *et al.*, 1995; Tan and Iatrou, 2001).

Rangelands of the sub-sector amount to 3200 km² (NSSG, 1995), corresponding to 40% of the whole area, and have a stocking rate 0.84 LU/ ha (ASG, 2003). They are privately or communally owned and grazed by livestock during the winter period. Sheep are the dominant species followed by goats while cattle are of secondary importance compared to small ruminants. Grazing starts in October when animals come back from the summer rangelands of other sectors (Pindus Mountain) and ends in middle May,

when they depart again for the mountains (Platis *et al.*, 2006). Wildfires are less frequent in this sub-sector.

Flocks of sheep and goats are pure or mixed with animals belonging to local breeds but improved with more productive ones. They are raised for milk and meat. Dairy products are several kinds of cheeses with the most important being the pheta cheese.

South-eastern Peloponnesus sub-sector (3c) involves the prefectures of Arcadia and Lakonia and amounts to about 8000 km² (NSSG, 1995). It extends from the sea level up to 2000 m. It includes both coastal areas and mountains with the most important being Mount Parnon. Major vegetation types in the sub-sector related to livestock husbandry are: (i) lowland phryganic vegetation with *Sarcopoterium spinosum* and of *Micromerium-Hypericum empetrifolii*, also found in the understory of open forests; (ii) open canopy shrublands of *Quercetalia ilicis* (maquis) and of *Quercus coccifera* (garrigues) and (iii) vegetation of *Daphno-Festucetea* (above timberline) (Quezel, 1964; Horvat *et al.*, 1974; Dafis *et al.*, 1997, 2001). Flora contains several rare and Greek or local endemic species (single-mountain endemics are 6,7% and Greek endemics are 12,6% of the total flora of mount Parnon; Tan and Iatrou, 2001) such as *Asperula elonea*, *Astragalus arganiotii*, *Bupleurum greuteri*, *Campanula asperuloides*, *Crepis heldreichiana*, *Linum hellenicum*, and *L. phitosianum* (Phitos *et al.*, 1995).

Rangelands of the sub-sector amount to 2800 km² (NSSG, 1995) corresponding to 35% of the whole area and have a mean stocking rate of 0.20 LU/ha. They are public forestlands communally grazed by livestock. Goats are the main livestock species followed by sheep while cattle are of limited importance. In the coastal areas and lowlands grazing is done during the winter months while in the summer animals move to higher elevations within the sub-sector. Wildfires are occasionally used to improve rangelands, especially to open up dense garrigues of kermes oak (*Quercus coccifera*) so that goats can penetrate them.

Flocks are pure or mixed, permanently attended by the shepherd and raised for milk and meat. Breeds are local but partially improved with more productive ones. There is a tendency for livestock husbandry to be decreased over the last few decades, particularly in the mountain areas. This abandonment will probably lead to a reduction of biodiversity since both plant and animal species as well as their habitats are closely related with livestock grazing (Bousbouras, 2008).

The Mediterranean south (islands) sector

This sector includes the Aegean islands and Crete. Geology is variable but mainly includes limestone and tertiary deposits (Nakos, 1977). Climate ranges from xerothermic to attenuated thermo-Mediterranean with more than 100 biologically dry days (Mavrommatis, 1980). Plant growth occurs during the winter months (with the

exceptions of the high mountains of Crete) while the summer period is long and dry (Kyriakakis and Papanastasis, 1993).

For livestock husbandry, the importance lies mainly on phrygana which are the dominant vegetation type (*Cisto-Micromerietea*, *Hyperico empetrifolii-Micromerion graecae*, *Corydorthymion*) composed of several species of dwarf shrubs, spiny or aromatic (Barbero and Quezel, 1980). They are seasonally dimorphic species characterized by the replacement of the large winter leaves with smaller ones in the summer period in order to conserve water (Margaris, 1981). In addition, they are very flammable (Papanastasis, 1977). The most common of them are: *Sarcopoterium spinosum*, *Corydorthymus capitatus*, *Euphorbia acanthothamnus*, *Genista acanthoclada*, *Phlomis fruticosa* and *Ph. lanata*. In addition, several herbaceous species grow under or among the dwarf shrubs. These latter species belong to several botanical families but the most popular ones are *Leguminosae* followed by *Compositae* and *Gramineae*. Species richness was found to be about 20 species/0.25 m² (Papanastasis *et al.*, 2002). Phrygana are distributed from sea level up to the high mountains. Pastoral wildfires are also used in this sector in order to control the unpalatable phryganic species. According to Margaris and Koutsidou (1998), fires and overgrazing are the main driving forces of desertification in the Aegean islands. Furthermore, Koutsidou and Margaris (1998) claim that protection from grazing improves both plant diversity and evenness while the dominant phryganic shrub *Sarcopoterium spinosum* is reduced. On the contrary, Tsiourlis *et al.* (1998) found a reduction of woody plant cover as a result of the combined effect of wildfires and overgrazing but plant diversity was not affected, particularly on sites based on limestone. In a more detailed study, however, carried out on phryganic rangelands, Papanastasis *et al.* (2002) found that overgrazing by itself does not affect plant diversity; the latter is negatively affected when overgrazing is combined with wildfires.

Grasslands are limited in this sector and mostly found on high elevations, mainly in dolines of limestone (Egli, 1991). They consist of a high number of herbaceous species, mainly annuals, but some dwarf shrubs can also be found (*Thero-Brachypodietea*). Species richness in these ecosystems amounts to 14 species/ 0.25 m² (Papanastasis *et al.*, 2002). Heavy grazing in these grasslands of Psilorites mountain results in a richer seed bank in the soil than in areas protected from grazing (Kazakis and Papanastasis, 2001).

Garrigues of evergreen or deciduous shrubs are also present in this sector. The most common species are *Quercus coccifera*, *Pistacia lentiscus*, *Juniperus phoenicea* in the low elevations and *Acer sempervirens* and *Berberis cretica* in the higher ones (Papanastasis *et al.*, 2004a).

The sector is important for sheep and goats, while cattle have a very limited distribution. Grazing is done in the lowlands during the winter period, when the practice of pastoral wildfires combined with overgrazing is applied in several parts, particularly

in Crete. In the summer period, animals are either moved to higher elevations or to agricultural areas (e.g. cereals and olive groves) or kept in the lowlands and fed with hay and concentrates. In the latter case, animals are not shepherded. As a result, they graze uncontrolled and get to a semi-wild status, especially the goats (feral goats). Crete, especially its western part, is also the habitat of the wild goat *Capra aegagrus cretica* (Papageorgiou, 1990).

Forests in this sector are restricted to few areas depending on climatic and soil conditions. Main forest vegetation types are: (i) *Oleo-Lentiscetum*, *Acero sempervirentis-Berberidetum creticae*, *Lauro-Quercetum ilicis*, *Chamaecytiso creticae-Quercetum ilicis*, *Aristolochio creticae-Quercetum cocciferae* and *Prasio majoris-Ceratonietum siliquae*, which includes the major evergreen shrublands (maquis and garrigues) (Barbero and Quezel, 1980; Brofas and Karetzos, 2000); (ii) *Luzulo nodulosae-Cupressetum sempervirens*, *Junipero lyciae-Pinetum brutiae*, *Irido cretensis-Pinetum brutiae* (Barbero and Quezel, 1980) and *Rubio tenuifoliae-Juniperetum macrocarpae* (Gehu *et al.*, 1989) which includes the major coniferous shrublands and forests; and (iii) *Oenanthe pimpinellifoliae-Quercetum brachyphyllae*, *Pistacio lentisci-Quercetum brachyphyllae* (Barbero and Quezel, 1980), *Lathyro laxiflori-Castanetum* (Bergmeier and Dimopoulos, 2008), which includes the major deciduous broadleaved forests.

Among the two sub-sectors, Central Crete (**4a**) involves the prefectures of Heraclion and Rethymnon which amount to an area of about 4000 km² (NSSG, 1995). The area extends from the lowlands at the sea level up to mountains, of which the highest are Psilorites (2456 m) and Asterousia (1230 m). In this sub-section major vegetation types related to livestock husbandry are: (i) phrygic (*Cisto-Micromerietea*) vegetation classified mainly in *Hyperico empetrifolii-Micromerion graeca*, also found in the understory of open forests and shrublands of *Quercus coccifera*, *Acer sempervirens*, *Pistacia lentiscus* and *Cupressus sempervirens* and (ii) orophrygic (*Daphno-Festucetea*) vegetation mainly classified in *Astragalion creticae* (Barbero and Quezel, 1980; Dafis *et al.*, 1997, 2001; Bergmeier, 2002b). Flora contains numerous rare or local endemic taxa (almost 35% of high mountain flora) such as *Astragalus idaeus*, *Biarum davisii*, *Cephalanthera cucullata*, *Crepis auriculifolia*, *Epipactis cretica*, *Horstrissea dolinicola*, *Phlomis lanata* (Phitos *et al.*, 1995; Jahn and Schonfelder, 1995).

Rangelands of this sub-sector amount to about 1850 km² (NSSR, 1995) or 46% of the whole area and have a mean stocking rate of 1.60 LU/ha (ASG, 2003). This is a very high grazing pressure which has led to their desertification (Papanastasis, 1998; 2000). Land ownership is not clear, but farmers consider rangelands as private lands, a claim that is not accepted by the state. Sheep are the dominant species followed by goats while cattle are very few. In the lowlands, grazing is done during the winter period while in the summer animals are moved to higher elevations (Kyriakakis and Papanastasis, 1993).

In the past, rangeland forage was the only food to the animals but since the European subsidies started in the 1980's farmers feed their animals with hay and, especially, concentrates in order to maintain a high production. This additional feeding of the animals is also necessitated by the high number of livestock that farmers have in this sub-sector, which results in rangelands degradation and desertification (Ziogas *et al.*, 1998; Stefanakis, 2006).

Flocks of sheep and goats are pure or mixed, but they are not shepherded. Animals are either free to graze without the shepherd's attendance or, recently, confined to fenced areas. This free grazing usually makes the animal semi-wild, especially the goats. Both kinds of animals are raised for milk and meat, especially sheep (Volanis *et al.*, 2007). Goats are not always milked because they are semi-wild and used in this case only for meat production.

Dodecannisa sub-sector (**4b**) amounts to 2700 km² and corresponds to the homonymous prefecture. It consists of 12 inhabited islands with the largest being the island of Rhodes. Major vegetation types related to livestock husbandry are: (i) phrygic vegetation with *Sacropoterium spinosum* (*Cisto-Micromerietea*), *Salvia fruticosa* (*Prasio-Salvietum fruticosae*), *Coridothymus capitatus* (*Corydothymion*) that also found in the understory of open forests and shrublands such as *Juniperus oxycedrus* ssp. *macrocarpa* forests (Gehu *et al.*, 1989); (ii) grasslands of annual (*Thero-Brachypodietaea*); and (iii) perennial (*Festuco-Brometea*) herbs (Horvat *et al.*, 1974; Dafis *et al.*, 1997, 2001). Flora contains several rare and Greek or local endemic taxa such as *Centaurea lactucifolia*, *Consolida arenaria*, *Fritillaria rhodia*, *Ophrys umbilicata* ssp. *rhodia* (Phitos *et al.*, 1995).

Rangelands amounts to about 1250 km² (NSSG, 1995) or 46% of the whole area and have a mean stocking rate of 0.38 LU/ha (ASG, 2003). The ownership status of these rangelands is not very clear. Goats are the dominant livestock species followed by sheep while cattle are of limited importance. Livestock are not shepherded. As a result, grazing is uncontrolled often leading to serious damages not only to forests but also to arable lands or even to house gardens. According to Voulgaris and Theodoridis (2006), there is a big problem with overgrazing in the island of Rhodes that was aggravated in the 1980s and 1990s due to the large forest fires which restricted the available area to livestock. Also, Theodoridis *et al.* (2008) claim that overgrazing together with wildfires have a negative impact on the population of fallow deer (*Dama dama*), that is part of the natural asset and the historical and cultural heritage of Rhodes. Overgrazing was also recorded in the island of Chalki, which was further aggravated in the last 20 years as a result of the European subsidies to livestock husbandry (Christodoulou and Papanastasis, 2008).

In the past, both sheep and goats were milked but currently this is not a standard practice. The only mode of production is meat. Goats actually are semi-wild. In general, both animal species are not displaced from place to place. They usually stay in the same

rangeland grazing freely with their owners visiting them from time to time to feed or water them, especially in the summer months (Christodoulou and Papanastasis, 2008).

SUCCESSIONAL TRAJECTORIES

Human pressures on natural resources and rapid economic growth are frequently cited as main causes of environmental changes, including climate change and biodiversity loss (NERC, 2007). The first cause (human pressure and population growth) is widely recognized as a main destabilizing factor of pastoral systems in the West-Asian and Northern-Africa regions of the Mediterranean (Solh *et al.*, 2003). In these mostly developing countries, livestock farming still represents a primary activity for a large part of the population and regressive succession of vegetation types, caused by overgrazing, is a primary cause of concern. Some alternatives have been devised and partially implemented to mitigate this threat (ICARDA, 2004; Rischkowsky *et al.*, 2004).

The second cause (economic growth) may apply more directly to developed countries of the N Mediterranean shore (Spain, Italy and Greece), to which this research deals with. This cause is not related to high extractive rates related to economic growth, but to the general improvement of the economic framework. Alternative job opportunities in other economic sectors is acting as an external pressure motivating abandonment of less developed and less favoured areas, where most LSGS are operating. It seems that in a scale of progressive economic development and changing sectoral economic activities, the primary sector in the LFA gets destitute (Caballero *et al.*, 2007). Paradoxically, the potential environmental threat in the LFA of developed Mediterranean countries is not caused by human pressure, but for depopulation and abandonment.

We have confirmed this trend in the large sample of LSGS of the three developed countries and related individual profiles of the previous section. The question now is how this trend is affecting to main environmental changes. Although many other environmental functions can be affected (e.g., C and N balances, climate change, soil and water quality, erosion and wildfire control), we will deal mainly with changes in land use and vegetation types caused by abandonment and its relationship to biodiversity as valued by species richness (Poshold *et al.*, 2004; Lindborh and Erikson, 2005).

Change in vegetation composition to more mature types after abandonment is a long-lasting process, especially in Mediterranean environments, where severe climatic and soil constraints slow succession. In most cases, we can only value a transitional state depending on the time scale (Cingolani *et al.*, 2005). However, in some individual profiles of LSGS, such as in the central Pyrenees, the Alps and the Apennines, we have observed long-lasting periods of abandonment that may allow comparison with more mature successional states.

Frequently, transitional and advanced states are characterized by shrub encroachment and further Mediterranean forest implantation. Under this scenario, pastoral use is severely limited. In Spain, for example, there is a long history of uprooting Mediterranean forest to create pastureland during the Mesta times (Rodríguez, 2001). Under abandonment, most of these pastures reverted to shrubland and forests. In more recent times, cultivation of steeply or less quality soils was incentivized by a self-sufficiency rural economy or lured by insensitive schemes of policy support. In the Pyrenean valleys, most cereal plots in the hill slopes were abandoned in the past 50 years or were used as hay meadows (Fillat, 2003). Otherwise, in Castile-La Mancha, some one million hectares of natural pastures fell to the plough in the past 50 years. Low productivity potential and a scenario of policy changes, with less cultivation incentives, may revert some of this land to natural vegetation. In any case, cultivation, pastoral use and the absence of nearby propagules are main brackets of vegetational succession towards more covered landscapes. Nowadays, there is much less human pressure to revert covered landscapes to cultivation or pastoral use, the reason why post-cultivation and post-grazing scenarios are more common in the case studies presented in this section. In some cases, technical improvements or farmers' practice include mechanical or controlled fire of shrubby types for better access and quality of pastoral resources (Bernal *et al.*, 2001; González Hernández *et al.*, 2006). This reversion usually takes the form of small patches (clearings) and almost never large tracts of shrubby vegetation. In these cases, we may value the potential vegetation richness in the clearings, although herbaceous cover can be at risk by nearby ecotones if human intervention is not maintained.

Historically, livestock grazing in Greece has been irrational leading to land degradation mainly due to the communal use of rangelands. To solve the problem, Forest Service applied extensive reforestation projects in these areas, since most of them belong to forest lands. This is because livestock grazing is prohibited in reforested areas under the forest law for at least 5 years for sheep and cattle and for 10 years for goats so that the planted saplings grow enough to get out of reach of the grazing animals. The same law is also applied in grazed forests that are put under natural regeneration. This policy forced many livestock farmers to abandon shepherding in rural areas, since the area allowed to livestock grazing was reduced, but resulted in the conversion of several rangelands into forests. Nowadays, reforestation is not applied anymore chiefly because forest is coming back in underutilized or abandoned rangelands through natural succession. Livestock husbandry has largely moved to lowlands or become semi-intensive with animals being fed more and more with feedstuffs in the barn instead of grazing in rangelands. This evolution however has not been uniform all over the country and the various sectors display different succession trajectories.

Case-studies from Spain

The Euro-Atlantic sector

The main natural vegetation types in this sector (see Section III) have been extensively changed for human intervention (or lack of it) throughout two main axes: reforestation and grazing. More than half the current forested area is introduced species of pines and eucalyptus and mixed forests. In this case, the focus is on timber production, although grazing the forest undercover in Galicia (**1a**) is an old tradition (Silva-Pando *et al.*, 2002).

The effect of grazing brings about some changes in the forest undercover. Light grazing the undercover of *Pinus pinaster* and *P. sylvestris* after 10 years leads to a reduction of the coverage and shrub biomass, important for the control of wildfires. Further, to a dominance of grasses such as *Agrostis capillaris*, *A. curtisii* and *Avenula sulcata*, and to the appearance of some forbs (Rigueiro, 1985; Silva-Pando *et al.*, 1998). High animal densities, however, may prevent tree regeneration and reduction of biomass of grasses (*Agrostis* spp., *Brachypodium* spp., *Pseudarrhenatherum*), with rapid recover after reduction of density or animals' removal. Grazing the forest undercover can be a sensible practice both from the economic and ecological point of view, but the forest regeneration potential and the grazing species and stocking should be controlled. For example, browsing preferences of cattle is for pines and eucalyptus and horses for oak, while goats for oak and pines (Silva-Pando *et al.*, 2002). Extensive grazing in shrublands, currently covering some 35% of the regional rural area is of much importance for our research subject. The following is an example of grazing/post-grazing succession on Galician scrublands (González Hernández *et al.*, 2006).

A dense cover of heathland located at 650 m in the municipality of Monfero (A Coruña province) was mechanically uprooted in 1982. The dense cover was the result of a long period of abandonment with abundance of species in the following order: *Ulex europaeus*, *U. gallii*, *Erica mackaiana*, *E. tetralix*, *E. cinerea*, *Calluna vulgaris*, *Ilex aquifolium*, *Rubus* spp, *Pteridium aquilinum*, *Agrostis curtisii*, *A. capillaris*, and *Pseudarrhenatherum longifolium*. The dense shrub cover had up to 2 m height and biomass of some 30 t DM/ha, hindering grazing use. In a cleaned parcel of 11 ha, mixed sheep and goats (0.7 LU/ha) freely grazed from 1983 to 1997 and single horses from 1998 to 2000 (stocking of 1 LU/ha). During this grazing period (1983-2000), three vegetation inventories were performed (1992, 1994 and 1996). Further, animals were removed and a last post-grazing inventory was carried out in 2003 after three years resting period. Results showed that species richness almost doubled under the effects of cleaning and of sheep and goat grazing, with appearance of good foraging species such as *Dactylis glomerata*, *Lotus corniculatus* and *L. pedunculatus*. It was also relevant

the control of some heath species such as *Erica ciliaris* and *E. cinerea*, probably due to the presence of goats (Olivan and Osoro, 1998). More striking was the result obtained after three years of grazing rest. In this latter case, the number of species increased by a factor of four in relation to the composition of the original shrub cover. Although being unable to differentiate the effects of horse grazing and resting, this research stressed the braking effect of grazing on shrubby encroachment, the presence of species adapted to post-grazing succession and the implications of mixed grazing and grazing pressure (stocking-destocking) on species richness (González Hernández *et al.*, 2006).

The Pyrenean sector

Vegetation changes in the central Pyrenean valleys (**2b**) can be traced back for very long periods of time since the effects of cultivation and grazing abandonment have been recorded in some valleys from the beginning of the 20th century (Lasanta-Martínez *et al.*, 2005). An external and determinant factor influencing land use and pastoral changes has been the inability of shepherds to practice transhumance to winter pastures in the nearby Ebro valley. Large areas of the latter became irrigated with higher cultivation intensity and less opportunity for shepherds to use agricultural residues and fallow lands. In past decades, this trend was partially offset by provisioning animals with cultivated grain cereals and mowing pastures. In most recent decades, socioeconomic (migration of rural population to large cities) and land use changes have been paralleled. Most of the cereal cultivation plots have been abandoned in the past 50 years and the remaining cultivated land is mostly hay/grazing meadows. These changes affected mainly to hill slopes and the lowland, while summer upland pastures have been maintained. Currently, animal husbandry relies upon the latter for summer feeding and grazing and forages conserves from hay meadows on previous cereal fields.

The potential natural vegetation (see Section III) underwent changes under the processes of past cultivation and further abandonment and partial reforestation, affecting mainly to hill slopes. *Quercus pubescens* on the sunny slopes and *Pinus sylvestris* on the more shaded ones prevail between 800 and 1800 m. From 1800 m upwards, a subalpine community of *Pinus uncinata* is dominant (Rivas-Martínez, 1987). Both plant communities were affected by past human intervention with deforestation of *Quercus* for cultivation and the upper forestland to expand summer alpine pastures. Nowadays, most of the *Quercus* clearings are abandoned and shrub encroachment and pine recovering can be observed in some upper slopes (Fillat, 2003).

This short account of human influence on landscape management gives way to different transitional vegetation types with few mature stages under equilibrium. Molinillo *et al.* (1997) for the central Pyrenees have reported an account of successional stages, from abandoned fields to first entry of young trees. The factors influencing the

time-scale of successional stages and the intermediate or final stage of the colonization process have not been assessed, but we may hypothesize that land management before abandonment, intensity of cultivation, soil quality, slope orientation, rainfall, and the proximity of propagules may play a role (Brown, 1991). In general, colonization of herbaceous from the seed bank and first woody shrubs take place in the first 10-15 years, spreading and shrubby encroachment in the next 15-35 years, and some retraction of scrubs takes place over the 35-60 years. Finally, entry of first young trees may occur at 60-65 years after abandonment. Some variants of this trend were reported as to whether abandoned cereal fields are further used as grazing/hay meadows (if not, weeds quickly penetrate) or controlled fire revert intermediate to early herbaceous stages.

The main difference between abandoned crop fields and abandoned fields as meadows occur in the first 15 years. In the latter case, a strong competition takes place between the original forage species (*Trifolium pratense*, *T. repens*, *Poa angustifolia*, *Dactylis glomerata*) and weeds (*Hypochoeris radicata*, *Convolvulus arvensis*, *Daucus carota*, *Conopodium majus* and *Ranunculus bulbosus*), with progressive decreasing of the best forage species. In both cases, large spreading of *Genista scorpius* takes place between 15-35 years hindering grazing use in spite of the presence of some herbaceous plants under the shrubby cover. Further, the presence of *Genista scorpius* decreases and pastures generally improves. Disturbance of shrub cover after more than 20 years of abandonment by clearing or fire, a practice of shepherds in the past, improves accessibility and quality fodder, to a much higher degree by clearing. Nevertheless, *Genista scorpius* showed a strong recovery, even more than in non burned fields.

Abandoned fields, currently used as hay/grazing meadows, are a source of species richness in the central Pyrenees. Their maintenance through grazing/hay use and regeneration perspectives is of concern in many European countries (Bekker *et al.*, 1997). Hay meadows communities originating from former cereal crop in the central Pyrenees were analyzed for their floristic composition and the soil seed bank under intensive and extensive managed plots (Reiné *et al.*, 2004). The first plot of 1.38 ha was converted from cereal to grassland 50 years before the control. It was managed as cut in mid-July, grazed twice a year (30 cattle for 2-3 days) and fertilized with cattle slurry (30-35 t/ha) and NPK 7-14-20 at 150 kg/ha (every two years). The second plot of 0.1 ha was converted to grassland 20 years before and only grazed (five cattle for one day) in spring and autumn. Gravimetric frequency of the floristic composition showed that the number of species was almost twice in the extensive managed plot, but management intensification significantly favoured plant species of nutrient rich conditions such as *Arrhenaterum elatius*, *Bromus hordeaceus*, *Festuca pratensis*, *Lolium perenne* and *Poa pratensis*. Extensive management favoured plant species adapted to mid and poor conditions and pioneer species and, consequently, was considered unlikely for restoring

species-rich grasslands. It was striking that both managements acted as a brake to the shrubby invaders, although in the case of the extensive managed plot the time scale cannot allow a conclusion.

The Inland sierras sector

Vegetation types in this sector are linked to soil types, altitude and rainfall distribution. Two main types of soils can be differentiated in the Spanish Sierras: the siliceous area on the West and the calcareous land on the East. The first, so-called “Macizo Hespérico”, consists of Paleozoic mountains, where siliceous rocks are dominant (ranges of Gredos, Guadarrama (see vegetation types in Section III), Sierra Morena, Montes de Toledo, and Penibética). The second, is made up of limestone, marl and conglomerates formed during the Miocene and Pliocene (Meso-Cenozoic mountains) and dominating the Ibérica and Bética ranges (Guerra, 1968).

On siliceous soils and in a cross section from river valleys to crest, crops and meadows occupy the lower altitudes with dense areas of *Quercus pyrenaica* (Iberian oak; *rebollares* or *mejojares* in Spanish) followed of other areas of pastureland and some pine species (mainly *Pinus pinaster* and *Pinus sylvestris*). Above the pine timberline, alpine pastures of *Nardus stricta* and *Festuca* spp. and *piornales* of *Cytisus oromediterraneus* are the main vegetation. Undercover vegetation under pine species is dominated by *Juniperus communis*, *Genista florida*, *Genista cinerascens*, *Adenocarpus hispanicus*, and *Cytisus oromediterraneus*. Shrubland species in *Q. pyrenaica* areas are *Cytisus scoparius*, *Crataegus monogyna*, *Calluna vulgaris*, *Erica scoparia*, *Cistus salvifolius*, *Halimium viscosum*, *Lavandula pedunculata*, *Thymus mastichina* and *Cistus laurifolius* (Ceballos and Ruiz de la Torre, 1971).

Quercus pyrenaica is a medium-size deciduous tree with great sprouting capabilities (stolons). Under the effect of frequent grazing or fire, the forest develops on a mass of shrubby shoots interspersed with herbage clearings of great grazing value (*bardales* in Spanish). Under grazing abandonment, as at present, the forest became dense and covered by under-story vegetation. Under these conditions, grazing is hampered and plant diversity decreases (Tarrega *et al.*, 2004; Tarrega *et al.*, 2009). These last authors have studied the effect of abandonment in two forest of *Q. pyrenaica* on the vegetation cover in the NW Spain (León) under conditions of Cambisols soil type, altitude 950-1100 m, slope of less than 15% and Mediterranean sub-humid climate (Table 4). The main conclusions of these authors were that species richness was higher in forest where dense undercover patches are interspersed with herbage clearings, and that herbage legumes are the species more rapidly affected by lower sunlight of dense forest and shrubby undercover vegetation (Fernández Santos *et al.*, 1996). Higher intra-habitat

diversity (herbaceous species) and higher inter-habitat diversity were found in areas of low grazing shrubby vegetation interspersed with herbage grazed clearings.

TABLE 4

Cover of the most abundant plant species in two forests of *Quercus pyrenaica* (roble dal de melojo) in the province of León (Spain).

Cobertura de las especies más abundantes en dos bosques de Quercus pyrenaica (roble dal de melojo) de la provincia de León (España).

Species	RV ^a	RC ^b
<i>Agrostis capillaris</i>	2.3	0.3
<i>Avenula marginata</i>	4.7	1.0
<i>Brachypodium pinnatum</i>	18.9	-
<i>Carex praecox</i>	9.2	-
<i>Festuca rubra</i>	11.5	3.5
<i>Lotus corniculatus</i>	0.1	0.2
<i>Trifolium repens</i>	0.5	-
<i>Bellis perennis</i>	0.5	-
<i>Hieracium pilosella</i>	2.7	-
<i>Hypochoeris radicata</i>	0.1	-
<i>Plantago lanceolata</i>	0.2	-
<i>Tuberaria guttata</i>	-	0.1
<i>Genistella tridentata</i>	5.9	-
<i>Artostaphylos uva-ursi</i>	-	46.5
<i>Calluna vulgaris</i>	-	5.5
<i>Erica australis</i>	-	0.2
<i>Quercus pyrenaica</i>	11.7	27.6
Σ Herbaceous cover	89.2	15.5
Σ Shrub and tree cover	23.8	83.0
Species richness	47	26
Dominance index	0.17	0.47

^aRV=Robledal de Vegaquemada (extensive sheep grazing and wood-gathering use).

^bRC=Robledal de Corcos (after 15 years of abandoning the same uses).

Adapted from Tárrega et al. (2004).

Martínez (2001, 2002) reported main herbaceous and shrubby species in the Gredos subsector (3c) and their utilization by wild ungulates such as the Spanish ibex (*Capra pyrenaica*) and indigenous meat cattle (Morucha, Avileña). Lower forage utilisation on

shrubby communities was observed in *piornal* (*Cytisus oromediterraneus*) than in *brezal* (*Erica* spp.). Livestock farmers manage controlled fire in the *piornal*, under permission, to increasing the hectareage of pastoral herbaceous communities. However, the *piornal* invasion is widespread under conditions of grazing abandonment and, under dense cover, almost deprived of herbaceous vegetation.

A third case study for siliceous inland Sierras is reported in the Sierra Morena range (4b). The original Mediterranean forest, dominated by *Quercus rotundifolia* on steeply soils, was uprooted for cultivation of olive groves over the first half of the 19th century (some 30,000 ha in the county of Los Pedroches, province of Córdoba). Remnants of the original vegetation (*manchas de monte* in Spanish) remained on the crests of the hills, determining an interspersed landscape of *manchas* and olive groves. The olive business is currently under risk of abandonment due to low productivity potential and high labour-intensive operations, and is mainly maintained on EU subsidies. Occasional cultivation and complementary sheep, horses and Iberian pigs' grazing are the brakes for recolonization from the ecotones. Two olive farms of 30 and 60 ha, separated by 2 km, were surveyed for species composition of different habitat types. Results showed that species richness was much higher in olive fields than in shrubby patches (*manchas*), with dominance of hemicryptophytes and therophytes in the first habitat type. However, both habitats shared most phanerophytes indicating transference of propagules from the adjacent *manchas* and the recolonization process being underway. The number of juveniles and adults of the most representative species (*Quercus rotundifolia*) in olive fields assessed this latter process. In the two farms surveyed, 18 and 6 plants/ha were found, respectively, suggesting higher interspersion of *manchas* in the first or higher cultivation and grazing intensity in the second farm, without the study being able to differentiate the factors of influence (Sánchez, 2003). In any case, spreading of propagules in harsh Mediterranean environments, in danger of abandonment, is a much-needed line of research (Marañón, 1995; Herrera, 1998, 2000; Castro and Robles, 2003).

On calcareous soils, pine forests of *Pinus nigra* subsp. *salzmannii* (*pino laricio* or *negral* in Spanish) and *Pinus halepensis* (*pino carrasco* in Spanish) are dominant in the calcareous sierras of the Iberian (3a, 3b) and Bética ranges (3d). In the shrubby undercover vegetation, some common species are *Amelanchier ovalis*, *Berberis hispanica*, *Rhamnus infectoria*, *Prunus mahaleb*, *Crataegus monogyna*, *Ononis aragonensis*, *Aphyllanthes monspeliensis*, *Salvia lavandulifolia*, *Lavandula latifolia*, *Thymus vulgaris*, *Juniperus communis*, *Juniperus sabina*, *Quercus coccifera*, *Rhamnus lycioides*, *Pistacia lentiscus*, *Pistacia terebinthus*, *Genista scorpius*, and *Anthyllis cytisoides*. Some herbaceous species of the genus *Brachypodium*, *Stipa*, *Koeleria*, *Helictotrichon* and *Festuca* such as *Festuca rubra*, *Festuca scariosa* (*lastón*), *Brachypodium retusum* (*cervero o yesquera*), *Festuca hystrix*, and *Poa ligulata*, are dominant. Under open clearings and sheep grazing,

perennial natural pastures dominated by *Poa bulbosa* and some *Trifolium* and *Astragalus* species can take hold.

In the high mountains of Teruel (Albarracín, Gúdar-Valdelinares) at 1500-2000 m, pine forests predominate (*Pinus sylvestris*) intercalated with small woods of *Quercus pyrenaica* and hazel (*Corylus avellana*) in richer soils. The meadowlands are famous since ancient times as Mesta summer pastures (Mesta de Albarracín). Good legume species such as *Astragalus danicus*, *Medicago suffruticosa*, *Onobrychis hispanica*, *Ononis cristata* and others are present. In gravely or sandy soils or in the absence of grazing, *Calluna vulgaris*, *Cistus laurifolius* or *Halimium viscosum* can be invaders (Montserrat and Fillat, 1990).

The effect of a resting period of five years on species composition and vegetation cover was valued in Sierra Mágina (Bética Range), under conditions of steeply calcareous soils, vegetation dominated by *Pistacia terebinthus*, and previous sheep grazing. The short time-scale only allowed transitional changes. The number of species (60 and 62) and the Shannon index (5.14 and 5.11) did not change significantly between resting and grazed areas, respectively. However, vegetation cover increased significantly (from 35% in the grazed to 62% in the resting area), as well as the cover of hemicryptophytes and perennial grasses (*Brachypodium retusum*) over more grazing-adapted species such as *Leontodon longirostris* (Fernández Rebollo *et al.*, 2001). In a more semi-arid environment of SE Spain (3f), Navarro *et al.* (2006) studied the effect of medium-high grazing by sheep and goats on regressive succession of 12 plant functional types (shrubs, forbs and grasses). Perennial grass *Brachypodium retusum* (retuse torgrass) was found grazing-susceptible, while steppe grass such as *Stipa tenacissima* (feather grass) was grazing-adapted and indicator of regressive succession (Alados *et al.*, 2003).

The Inland plains sector

Anthropogenic influence in the succession of pastoral communities in the *dehesa* system (4a) derived mainly from eutrophication caused by cattle and sheep grazing, as indicated in Figure 1 (adapted from Rivas Goday, 1964). Grazing abandonment induces woodland and shrub encroachment with *Cistus* dominant communities, poor soils and disappearance of target pastoral communities. Grazing and some phosphate mineral amendments are the two basic management measures for the maintenance of productive and high biodiversity communities (Gómez Gutiérrez, 1992). In the best pastoral communities of *Poa bulbosa* and *Trifolium subterraneum* (Galán de Mera *et al.*, 2000), the first develops phenology in autumn and the second in spring. Sheep stocking during late spring should be lighted allowing seed maturing of *Trifolium subterraneum*. Sheep trampling during the summer allows the enriched seed bank for spring regrowth. Only a few years of adequate pastoral management are needed for developing grazing

communities in the *dehesa* system; shrub colonization may begin after 5-10 years of abandonment, depending upon the proximity of seed resources of woody species. The danger of shrubby invaders in the *dehesa* under abandonment (to *Cistus*-dominant communities) is always present, but the successional rate of change may greatly depend on the proximity of shrubby patches and propagules. Short-term (five years) post-grazing succession may increase tall grasses such as *Avena fatua*, but this short transition does not allow the shrubby invaders in the absence of nearby propagules (Fernández Rebollo *et al.*, 2007).

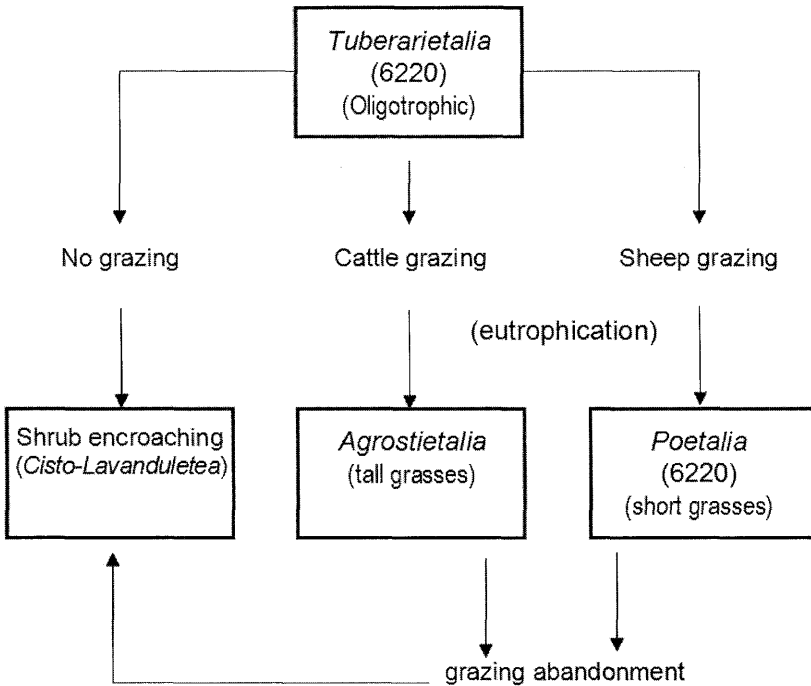


FIGURE 1

Effect of grazing on vegetation dynamics in the *dehesa* system (adapted from Rivas Goday, 1964; habitat codes of the Directive 92/43 (EC, 2003) are indicated between brackets).

Efecto del pastoreo sobre la dinámica de la vegetación en la dehesa.

In the Castilian Plain (4c), arable farmers and pastoralists represent a brake, limiting vegetation changes through secondary succession. Arable farmers have been driven to plough even the less quality soils by insensitive schemes of subsidies. This trend may change under current schemes of policy support and decoupling subsidies from

production (García *et al.*, 2006). Low cultivation intensity alternatives means soils of low productivity potential under several years of “green fallow”. The semi-natural, pioneer grasslands that can develop in this fallow may increase habitat suitability for steppe birds and increase availability of pastoral resources. Under a scenario of uncultivated land, the presence of small ruminants is of the outmost importance because they may represent the only brake towards woodland forest, maintaining open landscapes. Previous research in this study area has shown that small ruminant grazing and steppe birds were not uncongential and thus, an alternative management of low cultivation intensity and sheep farming integration can be envisaged (Oksanen *et al.*, 2006).

The recolonization process after nine years of abandonment of cereal cropping has been addressed by progressively surveying 25 fallow fields in the province of Toledo with floristic inventories between 1993 and 2002 (Hernández *et al.*, 2003). The total number of species with more than one presence was 76, of which 43% were grasses and legumes. Species from pioneer and subnitrophilous annual grassland were more abundant (*Thero-Brometalia*), but some important foraging perennial already appear (*Dactylis glomerata*). Under treatments, which include phosphate and mowing, the colonization by legumes was more rapid. This short transitional period did not allow the colonization by Mediterranean shrubs. The presence of woody vegetation is documented after 8-10 years of abandonment if nearby propagules are present, but only after more than 15 years in less accessible abandoned fields. In this case, a significant arrival of long-lived shrubs, like those proper of the Kermes oak (*Quercus coccifera*) garrigues may delay up to some 20-25 years (Peinado and Martínez Parras, 1987; Calabuig *et al.*, 1999; Caballero *et al.*, 2005). A synopsis of the main vegetation units represented in the cereal-sheep system of La Mancha and their successional linking is presented in Figure 2.

Most of the non-arable land in Castile-La Mancha (non-arable land is some 40% of TAL) consist of transitional and intermediate serial shrub communities, more or less covered depending on soil quality and history of grazing. Where grazing has been maintained, a mixed herbaceous and shrub community may share the land. On hill slopes of the Alcarria county (Cuenca province), Hernández *et al.* (2001) found up to 220 plant species with α -diversity of 28.61 ± 9.63 and β -diversity (Jaccard index) of 0.143 ± 0.03 . The vegetation inventories contained 16 Iberian endemics and subendemics: *Carduus platypus*, *Centaurea hyssopifolia**, *Digitalis obscura*, *Genista pumila*, *Gypsophila struthium**, *Koeleria castellana**, *Helianthemum squamatum**, *Herniaria fruticosa**, *Lepidium subulatum**, *Ononis tridentata**, *Scorzonera graminifolia*, *Sedum gypsicola**, *Teucrium gnaphalodes*, *T. pumilum**, *Thymus lacaitae**, and *Thymelaea pubescens*. These species represented 7.3% of the total number in the inventories. Most of them (marked with asterisk) are typical of gypsum-rich soils.

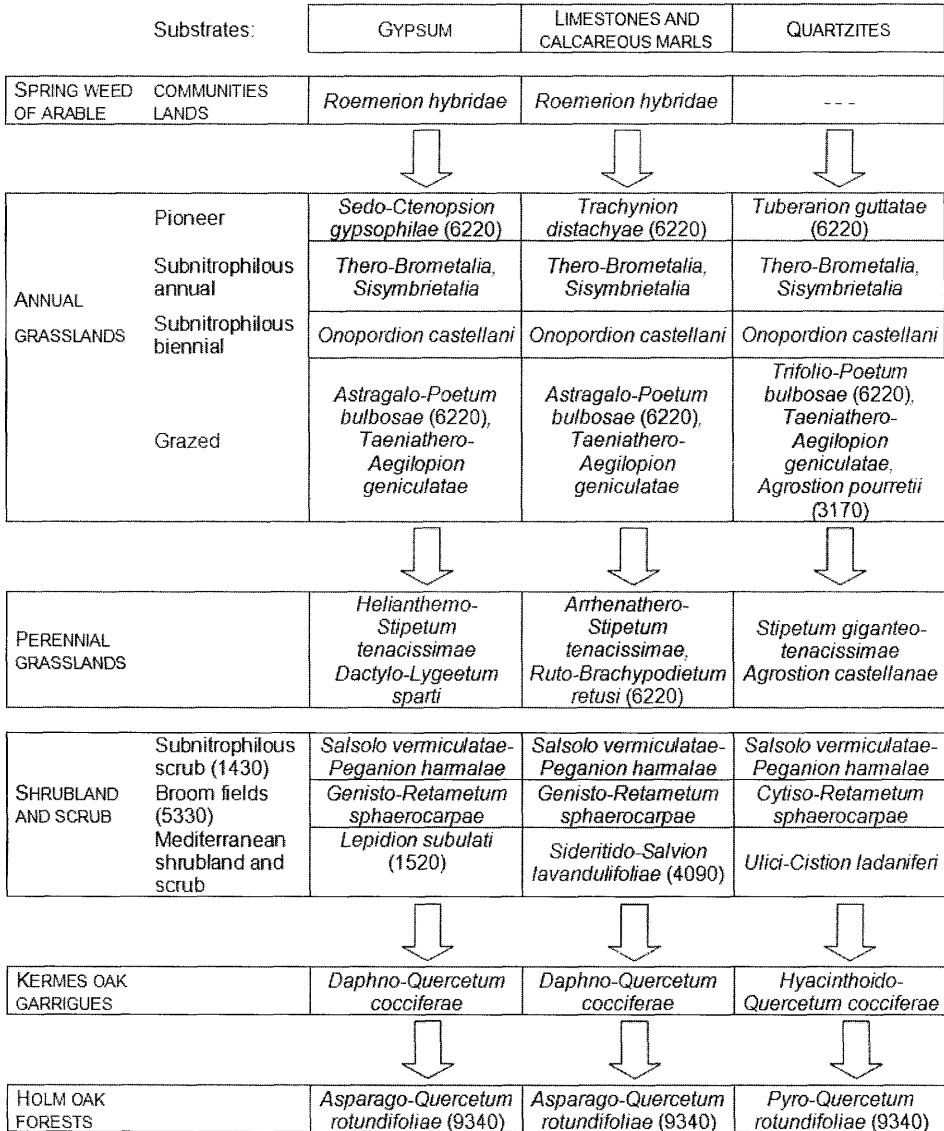


FIGURE 2

Successional lines linking the main vegetation units represented in the LSGS of La Mancha. Nomenclature of plant communities follows Rivas-Martínez *et al.* (2001, 2002); habitat codes of the Directive 92/43 (EC, 2003) are indicated between brackets.

Dinámica de los principales tipos de vegetación representados en el sistema pastoral extensivo manchego.

This transitional shrub-steppe vegetation (*eriales* in Spanish) has a very slow rate of progressive succession due to poor soils and low rainfall. With a time horizon of 50 years we can predict that an abandoned field should not go beyond the stage of a Mediterranean shrubland of *Quercus coccifera* (kermes oak) or, alternatively, a xeric long-lived tall grassland (*Stipa*, *Lygeum*) or a mix of both structures. Grazing, however, may delete progressive succession, reducing the cover of woody vegetation and favouring the expansion of herbaceous vegetation, and, in particular, some annual and perennial grasslands adapted to extensive grazing such as *Brachypodium retusum* (base-rich soils) and *Agrostis castellana* (siliceous soils) (Caballero *et al.*, 2005).

Case studies from Italy

The northern Italian sector

In the Alps, as in other mountainous areas of Europe, the declining profitability of agro-pastoral activities is causing widespread land abandonment, with consequent woodland expansion into previously cultivated areas (Cernusca *et al.*, 1999). In addition, almost 70% of the farms still operative today are running only as secondary source of income (Tappenier *et al.*, 2003). Therefore, woodland extent is increasing through natural regeneration by 0.5-1% per year, almost exclusively at expense of abandoned pastures (Barbaro *et al.*, 2001; Dirnböck *et al.*, 2003). Such change can be decomposed into two simultaneous processes. At medium-low elevations, land abandonment causes the loss of grassland fields originally managed for fodder production in association with the past livestock industry, an agro-pastoral system which dates back to 6000 years ago (Lichtenberg, 1994; Dirnböck *et al.*, 2003). At higher elevations, the rapid declining utilization of alpine pastures for livestock rearing is causing an upward shift of the treeline, originally lowered by human action (Dirnböck *et al.*, 2003).

In the Cottian Alps (**1a**) continuous surveys carried out from 1957 to 2003 allowed to define the vegetation dynamic in Valle Grana (600-2647 m). In the past, a high density of population caused a large substitution of the natural vegetation by chestnut wood and a general transformation of beech woods into coppices. With the neglect of agriculture and a partial abandonment of the silvicultural activities as well as the cattle breeding, the evolution of the vegetation gave rise to an invasion of uncovered areas, grasslands and chestnut woods. The more spreading grass is *Brachypodium caespitosum*, which is gradually invading abandoned meadows from low altitudes up to 1400-1500 m. Previously mowed prairies, are invaded by secondary birch woods and then by *Pinus sylvestris*. The Alpine pastures have been partly invaded by *Alnus viridis* and *Rhododendron ferrugineum* shrubs. Because of the rapid expansion of shrubs and woods some rare taxa such as *Argyrolobium zanonii*, *Stipa capillata*, *Koeleria vallesiana*,

Bupleurum baldense, *Centaurea triumfetti*, *Orchis* spp., *Ophrys* spp. are disappearing (Mondino, 2003).

In Susa valley the vegetation dynamic stages after abandonment were monitored between 1966-68 (Montacchini *et al.*, 1982) and 1994 (Siniscalco *et al.*, 1995) in some areas for which it was possible the reconstruction of the agronomic practices and the past land uses. The first ruderal dynamic stages are referred to *Xeranthemo-Brometum squarrosi*, the following to *Brometalia*, *Artemisietea vulgaris*, *Berberidion* and at the end of the succession to *Pinus sylvestris* woods, after 25-30 years under abandonment. In each dynamic stage alpha-diversity has been studied: the higher values are referred to the mown meadows and to the shrub communities used by wild animals (Siniscalco *et al.*, 1995).

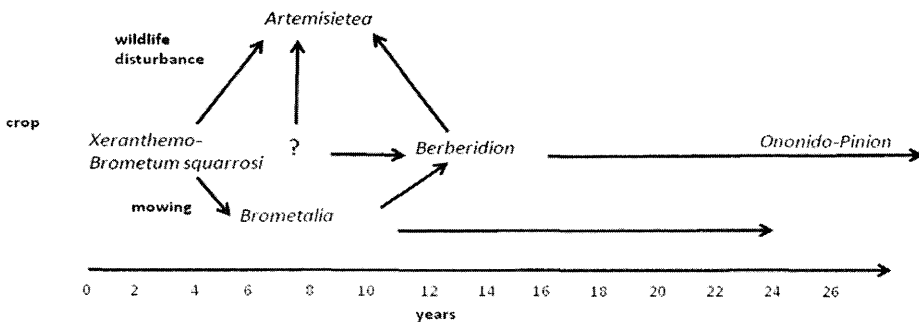


FIGURE 3

Vegetation succession in the Italian Alps (modified from Montacchini *et al.*, 1982).

Sucesión de la vegetación en los Alpes italianos.

Land abandonment and the decline of pastoral activities have consequences also for the structure and diversity of Alpine avifauna. The effect of grazing was particularly evident in the mountain belt. Grazing maintains open habitats by limiting tree and scrub encroachment, thereby favouring grassland bird species. Pastoral abandonment leads to an overall increase in avian diversity, but most species invading abandoned pastures are already common, whereas several grasslands bird species that are dependent upon grazed pastures have an unfavourable conservation status. Overall, in terms of bird conservation objectives, large-scale abandonment of long-established pastoral habitats and their complete replacement with scrub, or even forest, is likely to be detrimental (Laiolo *et al.*, 2004; Rolando *et al.*, 2006).

In the Alta Valtellina territory (**1b**) the effects of different grazing pressures on the biodiversity of grasslands was investigated in a area of 90000 ha of which 11000

occupied by grasslands mainly located in the upper Subalpine and Alpine altitudinal belts. The grassland flora in the area includes about 30 endemic taxa (7% of the total) and other very rare species such as *Sesleria uliginosa*, *Carex microglochin* and *Soldanella pusilla*. Where grazing is light, the grasslands maintain their natural physiognomy, and are enriched with few pastoral species. With the intensification of anthropic pressure, the pastoral species group expands and gradually replaces the primary component. When disturbance becomes excessive, it triggers ammoniacal degradation, determining a rapid drop of the agronomical and biological quality of the sward (Gusmeroli *et al.*, 2004). In an Alpine pasture of the Orobian Alps, Gusmeroli *et al.* (2000) pointed out a negative correlation between specific biodiversity and an intensive use of the sward. This poses some problems regarding the aim to finding an optimal balance between livestock production and grazing impact on plant diversity (Caccianiga *et al.*, 2000).

The effects of livestock breed and grazing intensity on plant biodiversity and sward structural diversity of semi-natural grasslands were also analyzed in Pordenone foothills (1c). Only grazing intensity had clear effects on vegetation diversity, the effects depending on site-specific characteristic. The structural diversity of the pasture was more affected by level of grazing intensity than by botanical diversity. Scimone *et al.* (2007) concluded that management systems to conserve diversity need to carefully consider the background environment, and that more knowledge of the mechanisms involved is needed at farm and landscape scales.

The central Italian sector

Compared to Northern-Europe, land abandonment started later in Central Italy, in the early 1950s, although it was afterwards widespread (Attorre and Bruno, 2003; Biondi, 2003). Due to the low level of utilization of the grasslands, shrub recovery is quite active and therefore plant landscape has been modifying with loss of specific and phytocenotic biodiversity (Biondi, 1996). The dynamics of the vegetation has been described throughout the model of vegetation series and in many cases the time necessary for the recovery by the most active communities was quantified (Biondi, 1990; Canullo, 1992; Biondi *et al.*, 2000; Ballerini *et al.*, 2000; Ballerini and Biondi, 2002).

In the mountain areas of Tuscany (2a) the difficult environmental conditions have historically forced local populations to develop adapted distinctive management practices and techniques to survive creating and maintaining landscapes of outstanding beauty. The abandonment of farming activities has clearly favored natural ecological succession and the degradation of the cultural landscape. Since 1832, there has been a dramatic decrease in landscape diversity in terms of landscape patches (86%) and land use (76%) as well as a related reduction in biodiversity. Among the classes of historical land uses with a strong tendency to disappear in the current landscape, meadows, pastures and

wooded pastures are listed. The reduction of grazing has contributed to the disappearance of specific type of forests called “pasture woods”, typical of the Mediterranean region (Agnoletti, 2007).

In the Umbro-Marchigiano Apennines (**2b**) the most frequent vegetation series in the hilly belt is represented by *Scutellario columnae-Ostryetum carpinifoliae*. *Spartium junceum* and *Fraxinus ornus* communities are among the most active and dominant communities in the grassland-woodland transition stages. These communities spread after the abandonment of agro-pastoral activities. It was established that *S. junceum* populations reach their maximum expansion in 20 years (Ballerini and Biondi, 2002). The process of invasion involved the most relevant grassland formations related to these vegetation series: *Centaureo bracteatae-Brometum erecti* belonging to the *Festuco-Brometalia* order is considered a priority habitat according with the Habitats Directive (EC, 2003).

The re-establishment of shrubby vegetation on secondary grasslands on calcareous substrata, important sites for orchids and other geophytes of great interest, was observed also in the *Cardamino kitaibellii-Fagetum sylvaticae* series located in the mountain belt of Lazio region (Attorre and Bruno, 2003; Biondi, 2003).

Some studies were directed to identify management systems that can be compatible to the conservation and regeneration of grasslands in pastoral areas of central Apennines where traditional livestock activities are still practised (Bagella, 2001b; Bagella and Roggero, 2004). Sectors with similar grazing value (Daget and Poissonet, 1971; Roggero *et al.*, 2002) and management were identified. For each sector, the actual stocking rate and the potential and minimal carrying capacity were assessed. Phytosociological, agronomic and management data were processed using a Geographical Information System and a phytosociological and phyto-pastoral map was created. Because of a continuous stocking over a wide grassland area, rangeland sectors had different levels of pastoral utilization. Xerophile grasslands (*Asperulo purpureae-Brometum erecti*) showed the highest stocking rate, while in some mesoxerophile grasslands (*Brizo mediae-Brometum erecti*) the stocking rate was even too low. The uneven spatial distribution of the stocking rates was recognized to be one of the most important factor of the grassland degradation and the re-establishment of shrubs. Therefore, to promote grassland renovation and conservation, it would be desirable to improve the grazing management by exploiting the grazing behaviour of different animal species and introducing some devices (water points, small fences, etc.) to redistribute the stocking rate according to the carrying capacity of the different sectors.

Abandonment of grasslands results in an early successional stage with progressive litter accumulation and increasing dominance of few perennial grasses. This is followed by shrub and woody encroachment with obvious changes in the structure and

composition of the vegetation (Tilman, 1987). A further threat to grassland diversity is nitrogen eutrophication. A 3-year field experiment in Central Italy species-poor grassland investigated the effects on productivity and species diversity of addition of nitrogen fertilizer, coupled with removal of plant litter and artificial cutting (Bonanomi *et al.*, 2006). The specific hypothesis was that nitrogen addition would increase living biomass and decrease species diversity, while disturbance by vegetation cutting and litter removal would produce opposite effects. Both nitrogen fertilization and vegetation cutting significantly affected aboveground biomass and species diversity of the grassland community. Cutting obviously reduced aboveground biomass but increased species diversity, whereas nitrogen enrichment markedly increased aboveground biomass but maintained low species diversity. Litter removal and cutting had strong negative effects on many of the perennial species especially on the dominant grass *B. rupestre*, where the negative effects of litter removal were reduced by nitrogen application. In contrast, the annual and biennial species generally showed positive responses to both litter removal and vegetation cutting. *B. rupestre* is known for its competitive ability in absence of grazing and mowing, which can result in rapid competitive exclusion in invaded grasslands (Biondi, 1996; Bagella, 2001a; Bonanomi and Allegrezza, 2004) and in the specific case species diversity was negatively related to aboveground biomass of *B. rupestre*.

In the central Apennine, several endangered animal species strongly dependent by landscape structure are present. Among them several endangered passerine species, like rock sparrow (*Petronia petronia*), ortolan bunting (*Emberiza hortulana*), red-backed shrike (*Lanius collurio*), occur on traditional farming and pastoral systems; these systems are now undergoing a serious decline, due mainly to economic and policy factors. The most important landscape changes were an expansion of woodland and scrubland at the expense of complex field mosaics, which were abandoned, and an overall decrease of vertical elements and structural diversity in the areas still being farmed. These highly significant changes affected also the correlations between variables. All of the three bird species showed an association to landscape features, which were subject to significant change, such as hedgerows, untilled land, bushes and trees. The long-term effects of land abandonment are likely to be a loss of habitat for farmland birds (Scozzafava and De Sanctis, 2006).

The southern Italy and Sicily sector

The transhumance of flocks from the mountains of Abruzzo and Molise in summer to the plain of Puglia was already practiced by the pre-Roman populations. It was later reorganized in the Middle Ages and in the first half of the fifteenth century by Alfonso I of Aragon which started to control the transhumance with a fiscal institution denominated

“Regia Dogana della Mena delle Pecore di Puglia”. In order to encourage winter grazing the area of public pastures was increased in Puglia and along the coast of Abruzzo and Molise with the creation of the “Tavoliere doganale” extending for about 362000 ha. To further increase the grazing land areas along the sheep tracks (*tratturi*, *tratturelli* and *bracci* of decreasing width respectively), grazing areas were designated for use during the migration (Paone, 1987), reaching an overall length of around 3000 km and took up more than 30000 ha. Nowadays, very little evidence remains of this great phenomenon: the winter pastures are cultivated while the summer pastures have been abandoned and have been taken over by secondary successions. The area named “Bosco dell’Incoronata” (3a) is one of the few areas where the sheep rearing landscape has survived, providing rare and valuable evidence of a natural and anthropic vegetational landscape which merits preservation. Pastures belonging to the class *Poetea bulbosae*, which could be maintained only by permanent flocks present a general impoverishment of the floristic composition, probably due to the overgrazing of the cattle which have replaced sheep or are replaced by cosmopolitan communities of the *Polygono-Poetea annuae* class (Venanzoni *et al.*, 1993). Negative effects were manifest also on fauna in particular on birds. In fact many species are disappearing from Apulia: stone curlew (*Burhinus oedicanus*), black-headed bunting (*Emberiza melanocephala*) and, in particular, little bustard (*Tetrax tetrax*) (Petretti, 1988).

Sicily (3d) may be considered representative of the environmental conditions and transformations occurring in the Mediterranean area. Land use change plays a destructive role on some habitats, such as wetlands: their reclamation caused extinction of some bird species once breeding in Sicily (Massa and La Mantia, 2007). Nowadays, in Sicily, the highest number of threatened plants is linked to open habitats, as grazed grasslands or even grain crops (Pasta *et al.*, 2006). The available data analysis point out as the reduction or the disappearance of mountain agro-sylvo-pastoral systems in Sicily affects the biodiversity value. The depopulation can produce a reduction of grazing pressure and, as a consequence, a forest recovery but sometimes, because of opposite phenomena (e.g. wildfires), this process is stopped (Rühl *et al.*, 2005; Rühl and Pasta, in press) and in some cases an overgrazing is observed (La Mantia *et al.*, 2004). The survival of 241 taxa, mainly heliophilous, in Sicily, is grazing-dependent. Nevertheless, it is necessary to consider in some cases direct or indirect damages due to pastoral activities, particularly overgrazing (Pasta *et al.*, 2006).

The Sardinian sector

The study of the Sardinian agricultural landscape is rather complex because it has developed from a disparate and original culture. Without an understanding of this culture and knowledge of its history, it is impossible to conceive the meaning of the

present Sardinian landscape (Pungetti, 1995). Brigaglia (1982) observes that the social organization of the island, based on community land management, developed a diffuse sense of land possession without formal legal ownership. Moreover, the shepherds never mixed with peasants and became isolated. Different land use patterns developed according to both geography and the type of community, which inhabited each site. As with other Mediterranean areas (Meeus *et al.*, 1988), Sardinia has undergone a transformation in landscape from 'sylva' to 'ager', from a primitive landscape of Mediterranean forest to an agricultural landscape, with wheat fields in the plains, vineyards on the slopes, and pastoral lands in the highlands.

Traces of human activities are also evident in the Sardinian agricultural landscape. However, here, more than in other Mediterranean areas, the balance between man and nature was maintained until half a century ago. Thus, the desirable ecological function of man towards nature was performed throughout history. In recent decades a radical transformation of Sardinian agriculture, due to the EC agricultural policy, the economic integration with the rest of Europe and the crisis of cereal growing, have dislocated the traditional island economy (Mattone, 1984). Large areas of land have been removed from agriculture, due to the spread of tourist facilities and urban expansion along the coasts (Aru *et al.*, 1984). After the Second World War, however, a strong impact on territory can be ascribed to a deep change in the Sardinian society, namely from agro-pastoral to urban. In landscape, the evidence of this circumstance is: (i) the increase in abandoned lands previously used for agriculture; (ii) the spread of greenhouses in the cultivated area. A loss of agro-pastoral culture, furthermore, emerges not only in society, but also in landscape with the vanishing of old patterns and elements such as stone walls, bush fences, vernacular buildings and trees (Pungetti, 1995).

A multi-scale approach on the consequences of land use changes on the distribution of terrestrial birds within a Mediterranean landscape was performed in some islands of La Maddalena Archipelago (North-eastern Sardinia), which is a National Park since 1996, where grazing abandonment and high tourist pressure modified patterns of land use (Coreau and Martin, 2007). The main vegetation trajectories in the Park are represented by the thermo-Mediterranean holm oak series, *Prasio majoris-Quercetum ilicis phyllireetosum angustifoliae* and the Phoenicea juniper series, *Erico arboreae-Juniperetum turbinatae* (Biondi and Bagella, 2005). In the examples studied, vegetation composition and landscape changes that resulted from land abandonment negatively affected birds depending on open areas or low matorral such as *Anthus campestris*, *Saxicola torquata*, and *Sylvia sarda* or on heterogeneous landscape such as *Sylvia cantillans*. The distribution of *Anthus campestris* was linked to variables associated to grasslands. The decline in number and area of grassland patches seems to be associated with the decline of this species. Similarly, the distribution of *Saxicola torquata* was

mainly related to percent cover of grassland. The decrease in grassland cover seems to be the mechanism involved in the decline of this species. *Sylvia cantillans* was associated both to the number of grassland patches in the landscape, and to the maximal vegetation height at the local scale. This species depends on heterogeneous habitat structure (Martin 1992; Martin and Thibault, 1996) and landscape homogenization might explain its relative decline. *Monticola solitarius* was mainly related to the percent cover of rock and bare soil (Coreau and Martin, 2007).

Land abandonment in the La Maddalena National Park also affects the presence of some communities linked to the land use, which host rare or endemic species plants or are themselves considered habitats of European interest. These communities represent stages of the vegetation recovery, such as the annual grasslands of the association *Tuberario guttatae-Plantaginietum bellardi*, or the perennial grasslands of the associations *Asphodelo microcarpi-Brachypodietum retusi* and *Scillo autumnalis-Bellidetum sylvestris*. Also very specialized communities, such as the ephemeral associations *Romuleo requienii-Bellietum bellidioidis*, *Romuleo requienii-Colchicetum corsicae* and *Anthoxanto aristati-Agrostietum pourretii* or the perennial *Agrostio stoloniferae-Cyperetum badii*, which occupy little surfaces surrounded by the serial vegetation (Biondi and Bagella, 2005) and threatened by the expansion of shrubs as observed in several areas of the Mediterranean basin (Bagella *et al.*, 2009 a; b; Bagella *et al.*, 2010; Médail *et al.*, 1988). Some of the rare species hosted in these habitats are *Agrostis pourretii*, *Ambrosinia bassii*, *Aristolochia rotunda* subsp. *insularis*, *Arum pictum*, *Carduus fasciculiflorus*, *Euphorbia cupanii*, *Ferula arrigonii*, *Ornithogalum corsicum*, *Pancratium illyricum*, *Plantago coronopus* subsp. *commutata* (Biondi and Bagella, 2005).

Case studies from Greece

The Mediterranean mountains sector

Forests of the Mediterranean mountains sector were freely grazed in the past, as animals were crossing them on their way from the lowlands to the summer grasslands in the subalpine region and vice versa. Grazing kept the forests open, allowing the maintenance of a heterogeneous landscape with high biodiversity. At the same time, the same grazing was preventing the natural regeneration of forests, especially when it was intensive (overgrazing). In a study carried out in old stands of the *Pinus nigra* forests of the Smolikas Mountain, Vergos *et al.* (1992) found that the forest soil was compacted due to the heavy grazing by sheep and goats, which prevented natural regeneration; grazing prohibition for 4 years resulted in seedling establishment but not to a satisfactory degree unless the soil was mechanically cultivated with a ripper.

With the decline of transhumance and the reduction of livestock grazing in the Mediterranean mountain sector over the last few decades, natural regeneration is no longer hampered and forests are getting denser and expanding over openings and the neighbouring grasslands. In a diachronic study of landscape changes in Tymfi mountain (1a) between 1945 and 1995, Zomeni *et al.* (2008) recorded an increase of the area covered by shrublands (mixed evergreen-deciduous scrub with *Quercus coccifera*, *Juniperus oxycedrus* and *J. communis*) and forests (*Abies xborisii-regis*, *Quercus frainetto* and *Pinus nigra*) by 20% and 84%, respectively at the expense of croplands and grasslands; the latter were reduced by 93% and 15% respectively. All these changes occurred in an area situated between 500-2300 m. An even greater increase of forests (118%) at the expense not only of croplands and grasslands but also of shrublands was found by the same authors in a nearby area but with elevation ranging between 300-1400 m. One of the main reasons contributed to these changes was the significant decline in transhumance.

Similar results were found in other parts of the North Pindus sub-sector. In the Pertouli-Portaikos valley covering about 12450 ha, located at the south-eastern part of the sub-sector and extended on elevations from less than 400 to more than 2000 m, Chouvardas (2001) found that coniferous forests consisted of black pine (*Pinus nigra*) and fir (*Abies* spp.) as well as deciduous forests consisted of oaks (*Quercus* spp.) and chestnut (*Castanea sativa*) were increased by 15% and 32% respectively at the expense of grasslands; the latter were reduced by 32% between 1945 and 1992. The most important finding however was that the increase of the forest area was accompanied by an increase of the dense forests at the expense of the open and very open ones. It should be noted that part of the increase of the coniferous forests was due to the reforestation with black and brutia pines (*Pinus nigra* and *Pinus halepensis* ssp. *brutia*) up to 1960. This means that the succession trajectories from grasslands to coniferous forests were not caused only by natural but also by management factors. Socioeconomic changes with the most important one being the aging of the population, the decline of transhumance and the reduction of grazing pressure were considered as the main agents favouring forest expansion at the expense of grasslands.

A similar picture of increasing forest cover at the expense of grasslands due to the reduction of livestock husbandry activities between 1963 and 1998 is given by Mitka (2009) in an area of more than 10000 ha, located on the east slopes of Smolikas mountain and extended at an elevation from more than 600 to less than 1600 m. Here again, part of the increased forest cover was caused by pine plantations after the year 1993.

In discussing the succession of current forest vegetation to climax in the mount Tymphristos (1b), Dimitrellos (2005) suggests that the course will be different in the various elevation zones, but with the exception of the low zone (420-900 m), where

forest species changes will occur, no major such changes are expected in the other zones (900-2315 m). On the contrary, many more changes in forest species composition are predicted in the mount Killini (**1c**) by Dimoloulos (1993) in all elevation zones except the ones extended over 1500 m. Both studies however say nothing about expected changes in total plant species diversity in relation to livestock grazing.

The Mediterranean north sector

In general, successional trajectories in the Mediterranean North sector are the same as in the Mediterranean mountains. This means that the reduction of grazing activities in grasslands has led to shrub and tree invasion as well as to the increase of stand density in shrublands and forests. At the same time, however, there are significant differences between the two sectors. These differences lie on the facts that the Mediterranean north sector receives higher human pressure because it is closer to human settlements and the climate is drier than in the mountain sector.

Reforestation has been used in this sector as a means both to increase the forest cover and to stop soil degradation due to irrational livestock grazing. This practice was widely used in the Thrace sub-sector and to a lesser extent in the Central Macedonia sub-sector. As a result, several grasslands and open shrublands were converted to dense artificial forests, almost exclusively of pines (*Pinus* spp.). Such a practice has put pressure on livestock that had to concentrate for grazing on much lesser area thus leading to further overgrazing. On the other hand, an increased demand for arable land led to the conversion of the better soil quality grasslands into agricultural areas. In the mean time, socioeconomic changes in the last 30-40 years that dictated extensification or even abandonment of human activities including livestock husbandry have triggered secondary succession with woody species and forests invading grasslands. An additional reason for this development is the gradual sedentarization of livestock husbandry with animals being fed with hay and especially concentrates to substitute grasslands forage in order to increase milk yields. Socioeconomic changes affected shrublands, too where the traditional activity of collecting firewood was also discontinued leading to increased shrub densities.

In a diachronic study of land use/cover changes in Central Macedonia (**2b**) between 1960 and 1993, Chouvardas *et al.* (2006) found that deciduous oaks (*Quercus* spp.) and beech (*Fagus sylvatica*) forests had increased by 35%, shrublands dominated by the evergreen shrub *Quercus coccifera* had increased by 12% and arable lands by 10%, all of them at the expense of grasslands which were reduced by 71%. The most important finding of this study however was the fact that land use/cover changes were multidirectional (Figure 4) suggesting that during the 33 year period not only natural but also anthropogenic (management) factors were involved in determining the successional

trajectories of the vegetation. In order to interpret these changes, Papanastasis and Chouvardas (2005) developed a state-and-transition model involving four states (arable lands, grasslands, evergreen shrublands, and deciduous oak forests) and seven transitions (abandonment of farming activities, ploughing and cultivation, reduction of grazing pressure by goats, afforestation with pines and other species, reduction or complete cessation of coal and fuel wood collection, expanding arable farms and establishment of farm forests).

Succession of vegetation due to the reduction of livestock grazing pressure and firewood collection activities leads to shrub encroachment and to the conversion of grasslands to shrublands and forests. As a result, herbage yield and quality are reduced while browse production is increased (Karakosta and Papanastasis, 2007; Zarovali *et al.*, 2007). In addition, plant diversity, annual species and C4 grasses are reduced in favour of perennial herbaceous species and C4 grasses; also, legumes tend to decrease while forbs tend to increase (Papadimitriou *et al.*, 2004).

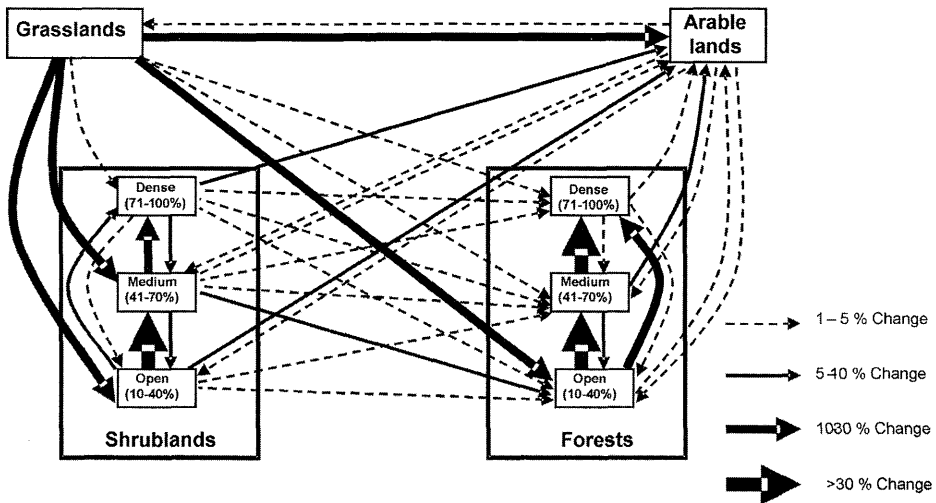


FIGURE 4

Multidirectional changes in land cover/uses because of socioeconomic changes including the reduction of livestock grazing in central Macedonia between 1960 and 1993 (the percentage change refers to the original extent of each type in 1961; Papanastasis and Chouvardas, 2005).

Cambios de cobertura de tipos de vegetación y usos del suelo en Macedonia Central entre 1960 y 1993, debidos a las modificaciones socioeconómicas y la reducción del pastoreo.

The Mediterranean south sector (mainland)

Successional trajectories in this sector are not identical with the other two sectors. Besides including areas close to human activities, which exert heavy pressure, this sector is also drier than the other two with wildfires being a common phenomenon that interacts with grazing and other human activities. Phrygantic rangelands that are present in this sector (**3a**) are considered as a pyro-zootic climax, which means that they are maintained by the combination of wildfires and overgrazing (Papanastasis, 1976) (Figure 5). Without wildfires, animals can not control the phrygantic dwarf shrubs which get dense even if overgrazing is applied, because they are unpalatable species. Also, without burning the same species die off after some years (e.g. 20-30) because they become decadent since they are pyrophytes and their regeneration by seeds or by sprouting are possible only after disturbance (burning) (Papanastasis and Romanas, 1977; Margaris, 1981; Arianoutsou-Faraggitaki and Margaris, 1989). In order to rationalize their grazing management in phrygantic rangelands, Papanastasis (1977, 1980) has suggested the replacement of wildfires with prescribed burning every 3-5 years and the application of moderate grazing with sheep and goats.

If both wildfires and overgrazing are stopped then phrygana might revert to shrub communities (garrigues or maquis) or even to forests. The latter could be hardwood, mainly of oak species (*Quercus coccifera* or *Q. ithaburensis* ssp. *macrolepis*) or coniferous forests of warm-Mediterranean species such as *Pinus halepensis* (Papanastasis and Gogos, 1983; Papanastasis *et al.*, 2004b).

The Mediterranean south sector (islands)

In the islands, successional trajectories are much more influenced by drought and grazing activities than in the mainland. This is depicted in the Psilorites mountain of Crete (**4a**), where continuous heavy grazing has resulted in multi-directional changes of the land use/cover types in rangeland between 1961 and 1989 (Bankov, 1998). These changes were strongly correlated with the activities in arable lands (Figure 6). This correlation suggests that livestock husbandry and grazing affect successional trajectories not only in rangelands but also in agricultural lands. On the other hand, phrygana can be converted to arable lands and planted with cereals or olive groves. The latter use that was recorded in western Crete shows again that the successional trajectories in the Mediterranean south is influenced by several management factors (Papanastasis *et al.*, 2004b).

As far as vegetation development is concerned, livestock grazing modifies secondary succession in old fields but does not revert it if less palatable or unpalatable woody species are established after arable land development (Papanastasis, 2007). Giourga *et al.* (1998) found early colonization of abandoned arable fields by woody species in the

Aegean islands, particularly *Sarcopoterium spinosum*. They attributed the high presence of this species to the heavy grazing applied in abandoned arable areas that resulted in the reduction of the more palatable annual species. Overgrazing of annual species leads to reduced competition with the woody seedlings and to their subsequent overgrowth (Papanastasis, 1977). On the contrary, protection from grazing favours annual species at the expense of the unpalatable perennials, including *S. spinosum* which is reduced (Koutsidou and Margaris, 1998).

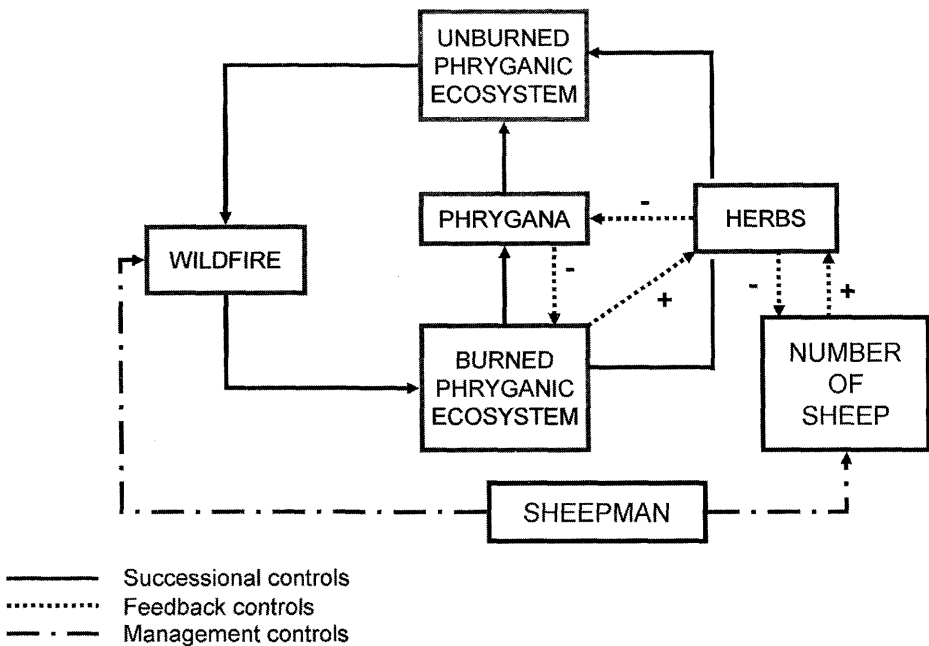


FIGURE 5

A generalized model of the interaction between fire, vegetation succession and sheep grazing in phryganic rangelands where overgrazing is combined with pastoral wildfires (modified from Papanastasis, 1977).

Modelo de interacción entre el fuego, la sucesión de la vegetación y el pastoreo ovino en pastos arbustivos (frigana).

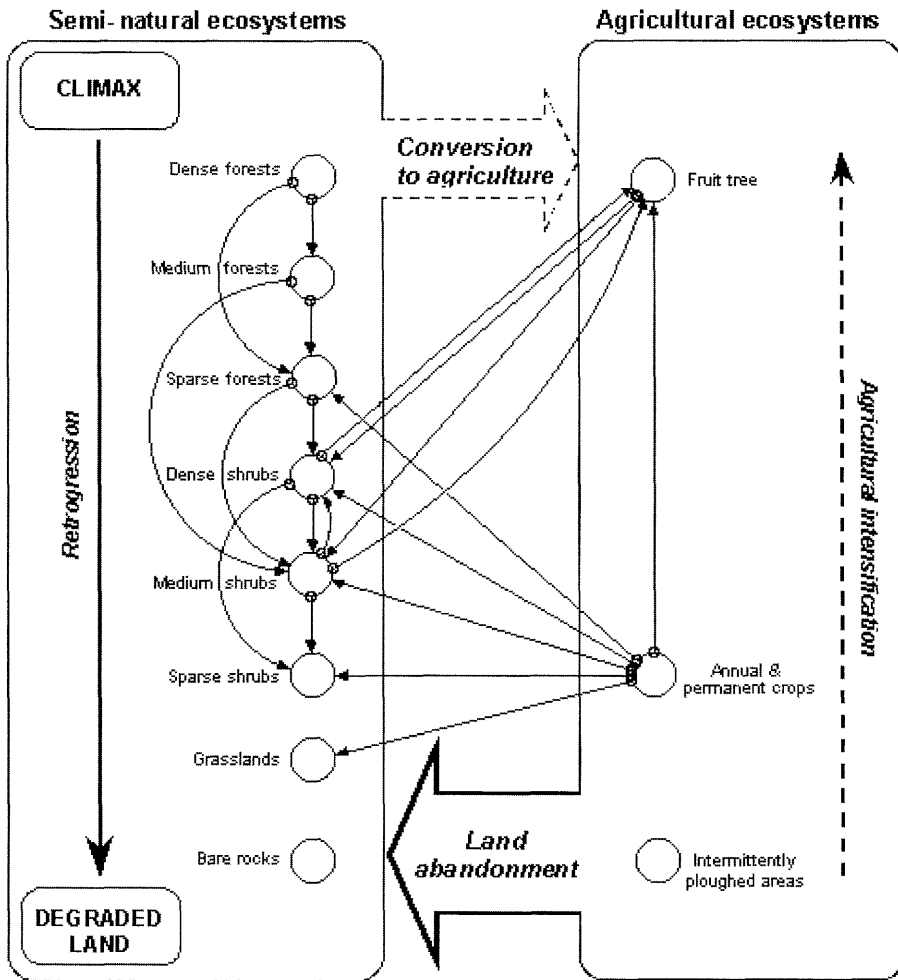


FIGURE 6

Retrogression of land cover/use types in an overgrazed Mediterranean landscape in the Psilorites mountain (central Crete) between 1961 and 1981 (Bankov, 1998).

Regresión de la vegetación debida a los cambios de uso del territorio y al sobrepastoreo en Creta central.

TARGET VEGETATION TYPES IN THE EU DIRECTIVE

Three are the main objectives of this section. First, to show in one case study (the Spanish *dehesa*, **4a**) the main vegetation units, at the association level, considered as habitat types of European interest for conservation (EC, 1992), and linked to grazing use. Second, to provide a link between the Natura 2000 habitat types (EC, 2003) and LSGS codes (Table 5, Spanish LSGS). Third, to compare the presence of representative species in grassland codes (Spain, Italy and Greece). By this way, we may better understand how the abandonment trend and successional trajectories, analyzed in previous sections, can affect to particular species and vegetation types.

Case-study for the *dehesa*

For the first objective, the main pastoral communities were grouped in eight phytosociological classes, 11 alliances (EC codes of Natura 2000) and 21 associations, following the Zurich–Montpellier school (Rivas Martínez *et al.*, 2001b). These pastoral communities are linked to siliceous soils and *dehesas* of Salamanca (Spain), where evergreen oak (*Quercus rotundifolia*) is dominant. The four-digit code indicated for the alliances corresponds to the EU Habitat Directive (EC, 2003 and Natura 2000 code) and the six-digit code of the 21 associations to the Atlas of Spanish Habitats (Rivas-Martínez and Penas, 2003). The following is a correspondence of both codes (adapted from Sánchez *et al.*, 2004).

ISOETO-NANOJUNCETEA

Agrostion salmanticae (3170-217010)

Pulicario paludosae-Agrostietum pourretii (217011). Ballicares (Spanish) with *Agrostis pourretii* as dominant species in soils with permanent edaphic humidity (near seasonal ponds) and late spring phenology.

Heleochloion (3170-217050)

Cypero micheliani-Crypsietum alopecuroidis (217051). Developed on seasonal ponds during late-summer or autumn.

JUNCETEA MARITIMI

Puccinellion tenuifoliae (1410-141030)

Plantagini maritimae-Camphorosmetum monspeliacae (141032). Halophilous pastures with chamaephytic and hemicryptophytic plants in dense and discontinuous patches dominated by *Camphorosma monspeliaca* and presence of *Plantago maritima* and *Puccinellia fasciculata*.

*FESTUCETEA INDIGESTAE***Hieracio castellani-Plantaginion radicatae (6160-516060)**

Corynephoros canescentis-Leucanthemopsietum pulverulentae (516062). Pastures dominated by the perennial grass *Corynephorus canescens*.

Thymo zygidis-Plantaginietum radicatae (51606B). Dominated by a mixture of chamaephytic and hemicryptophytic plants of small size in siliceous oligotrophic soils.

*HELIANTHEMETEA GUTTATI***Sedion pedicellato-andegavensis (8230-723020)**

Agrostio truncatulae-Sedetum lusitanici (723021). Ephemeral grasslands frequent in mountainous areas (supra- and oro-Mediterranean belts), dominated by carpets of *Sedum pedicellatum* subsp. *lusitanicum* developed on siliceous oligotrophic litosols and frequently associated with shrublands of *Cisto-Lavanduletea*. Some characteristic species of the class are *Linum gallicum*, *Hypochaeris glabra*, *Tuberaria guttata*, *Briza maxima*, *Ornithopus compressus*, *Eryngium tenue*, *Rumex bucephalophorus*, *Lupinus angustifolius*, *Logfia gallica*, *Silene gallica*, *Senecio lividus*, *Rumex angiocarpus*, *Brassica barrelieri* or *Silene portensis*. Some species of the genus *Vulpia*, *Aira*, *Anthoxanthum*, *Tolpis*, *Evax*, *Agrostis* and *Periballia* are also character species of lower levels of classification (Rivas Goday, 1964).

*POETEA BULBOSAE***Trifolio subterranei-Periballion (6220-522050)**

Eutrophic and anthropogenic pasture communities more evolved than the pioneer communities of *Helianthemetea*, favored by changes caused by sheep grazing, especially when housed over-night in the pastures (*redileo* in Spanish). This evolved and high quality class is called *majadales* in Spanish.

Festuco amplae-Poetum bulbosae (522052). Mainly supra-Mediterranean *majadales* are dominant in the *dehesas* of the province of Salamanca.

Poa bulbosae-Trifolietum subterranei (522055). Meso-Mediterranean *majadales* are dominant in the *dehesas* of Extremadura. Typical species of this association are *Poa bulbosa*, *Trifolium subterraneum*, *T. tomentosum*, *Biserrula pelecinus*, *Erodium botrys*, *Anthoxanthum aristatum*, *Juncus capitatus*, *Trigonella monspeliaca*, *Scorpiurus vermiculata*, *Medicago truncatula*, *Periballia minuta* and *Vulpia sciuroides* (Rivas Goday, 1964; Rivas Goday and Ladero, 1970).

Poa bulbosae-Trifolietum ornithopodioidis (522054). Consist of Supra-Mediterranean sub-halophilous *majadales* with *Trifolium ornithopodioides* of late spring and early summer phenology.

STIPO GIGANTEAE-AGROSTIETEA CASTELLANAE (6220).

The main association is *Festuco amplae-Agrostietum castellanae* (522514). It develops in deep soils with edaphic humidity (*ballicares* in Spanish). Other more xeric variants are dominated by either *Stipa gigantea* (*berceales* in Spanish) or *Festuca elegans* subsp. *merinoi* (*cerrillares*). Other associations are *Gaudinio fragilis-Agrostietum castellanae* (522515), *Leucanthemopsio pallidae-Festucetum elegantis* (522522), *Arrhenathero baetici-Stipetum giganteae* (522531), and *Centaureo ornatae-Stipetum lagascae* (522532).

MOLINIO-ARRHENATERETEA**Juncion acutiflori (6410-541030)**

Deschampio hispanicae-Juncetum effusi (541032).

Hyperico undulati-Juncetum acutiflori (541034)

Cynosurion cristati (6510-551030)

Festuco amplae-Cynosuretum cristati (551033)

Molinio-Holoschoenion (6420-542010)

Trifolio resupinati-Holoschoenetum (54201P)

Trifolio fragiferi-Cynodontion (3280-228040)

Trifolio fragiferi-Cynodontetum dactyli (228046)

Trifolio resupinati-Caricetum chaetophyllae (228047).

Pastoral communities on humid or wet, deep soils in which several tall grasses are dominant (*Poa trivialis*, *Phalaris bulbosa*, *Holcus lanatus*, *Poa pratensis*, *Alopecurus pratensis*, *Dactylis glomerata*, *Anthoxantum odoratum* and *Arrhenaterum bulbosum*). These species are frequently mixed with some rush species (*Juncus acutiflorus*, *Scirpus holoschoenus* and *Juncus conglomeratus*) and some *Trifolium* spp. (*T. campestre*, *T. pratense*, *T. repens*, *T. fragiferum*). Maintenance of these communities is linked to management by alternating mowing and cattle grazing.

NARDETEA STRICTAE**Campanulo herminii-Nardion strictae (6160-516040)**

Nardus-swards are less dominant types only located on deep valleys with dominance of *Nardus stricta* and some *Genista* spp. The main supra-Mediterranean association is *Genisto anglicae-Nardetum strictae* (516048).

Link of Spanish habitat types to LSGS

For the second objective, in Table 5, we have tried to link the spatial distribution of Spanish LSGS listed in Table 1 with the distribution of Spanish habitat types included in the Directive 92/43CEE. This whole list includes not only herbaceous but also shrubby vegetation and forests. This has been addressed by a rough comparison of the LSGS Spanish map with the Spanish Atlas of habitat type reported by Rivas-Martínez and Penas (2003) and Bartolomé *et al.* (2005). As the LSGS map only represents hot spots without defined borderlines, this exercise should be considered as tentative. Within this precaution, we have identified 75 habitat types linked to LSGS. This may represent 65% of the total Spanish types included in the Directive (116) and 34% of the European total (218). Some of these habitat types appear in more than one LSGS and other are almost exclusive of specific LSGS. Broadly, habitat diversity varied from 22 types in the *dehesa* system (**4a**) to 47 habitat types in the Central Pyrenees system (**2b**).

It is apparent that the pooled distribution of these vegetation communities takes up most of the Iberian Peninsula. The question for our specific line of research is how these communities are linked to the distribution of Spanish LSGS. In most cases, particular LSGS could be linked to several of the described vegetation types (Table 5). Most of these herbaceous communities are linked to traditional grazing use, but there is scant scientific evidence on the future of these listed communities under the present trend of grazing abandonment.

TABLE 5
Habitat types of the Annex 1 of Directive 92/43/CEE represented in the corresponding area of the Spanish LSGS^a.

Tipos de vegetación de la Directiva 92/43/CEE representados en los sistemas pastorales españoles.

LSGS code (Map 1)	Nº of types represented	List of habitat types (codes according to EC, 2003)
1a	23	3110, 3150, 3160, 3170, 3260, 4020, 4030, 4040, 4090, 6230, 6410, 6430, 6510, 7110, 7130, 7140, 7150, 91E0, 9260, 9230, 92A0, 9330, 9380
1b	37	3110, 3150, 3160, 3220, 3240, 3260, 4020, 4030, 4040, 4060, 4090, 5120, 6140, 6160, 6170, 6210, 6220, 6230, 6410, 6420, 6430, 6510, 7110, 7140, 7150, 7230, 9120, 9150, 9180, 91E0, 9230, 9260, 92A0, 9340, 9380, 9560, 9580
1c	34	3110, 3150, 3160, 3220, 3240, 3260, 4020, 4030, 4060, 4090, 6110, 6140, 6160, 6170, 6210, 6220, 6230, 6410, 6420, 6430, 6510, 7140, 7150, 7230, 9120, 9150, 91E0, 9230, 9260, 92A0, 9340, 9380, 9560, 9580
2a	32	3150, 3160, 3240, 3260, 3270, 3280, 4030, 4060, 4090, 5110, 5120, 5210, 6110, 6140, 6170, 6210, 6220, 6230, 6410, 6420, 6430, 6510, 7110, 7230, 9120, 9150, 9230, 9240, 9260, 92A0, 9340, 9430
2b	47	1410, 1420, 1430, 1510, 1520, 3140, 3150, 3160, 3220, 3230, 3240, 3260, 3270, 3280, 3290, 4030, 4060, 4090, 5110, 5120, 5130, 5210, 6110, 6140, 6170, 6210, 6220, 6230, 6410, 6420, 6430, 6510, 6520, 7140, 7220, 7230, 7240, 9120, 9130, 9150, 9180, 9240, 92A0, 92D0, 9340, 9430, 9530
2c	41	3150, 3160, 3220, 3240, 3260, 3270, 3280, 3290, 4030, 4090, 5110, 5120, 5130, 5210, 6110, 6140, 6170, 6210, 6220, 6230, 6410, 6420, 6430, 6510, 6520, 7110, 7140, 7210, 7230, 9110, 9120, 9150, 9180, 91E0, 9240, 9260, 92A0, 9330, 9340, 9430, 9530
3a	33	3150, 3160, 3250, 3260, 3280, 4030, 4090, 5110, 5120, 5210, 6110, 6160, 6170, 6210, 6220, 6230, 6410, 6420, 6430, 6510, 7140, 7220, 7230, 7240, 9120, 9180, 9230, 9240, 92A0, 92D0, 9340, 9380, 9560
3b	35	1310, 1410, 3140, 3150, 3250, 3260, 3280, 4030, 4060, 4090, 5110, 5130, 5210, 6110, 6170, 6210, 6220, 6230, 6410, 6420, 6430, 7220, 7230, 9180, 91F0, 9230, 92A0, 92D0, 9240, 9340, 9380, 9530, 9540, 9560, 9580
3c	34	3110, 3150, 3160, 3170, 3250, 3260, 4020, 4030, 4090, 5120, 5210, 6160, 6220, 6230, 6310, 6410, 6420, 6430, 6510, 7110, 7140, 7150, 9120, 91B0, 91E0, 9230, 9240, 9260, 92A0, 92D0, 9340, 9380, 9540, 9560
3d	27	1510, 1520, 3140, 3170, 3250, 3280, 3290, 4060, 4090, 5110, 5210, 5330, 6110, 6170, 6220, 6420, 6430, 7210, 91F0, 9230, 9240, 92A0, 92D0, 9340, 9530, 9540, 9560

3e	31	3110, 3140, 3150, 3170, 3250, 3260, 3280, 3290, 4030, 4090, 5210, 6170, 6220, 6410, 6420, 6430, 7140, 7150, 91B0, 91E0, 9230, 9240, 92A0, 92B0, 92D0, 9330, 9340, 9380, 9530, 9540, 9560
3f	22	3250, 3280, 3290, 4090, 5210, 5330, 6160, 6170, 6220, 6230, 6420, 6430, 7140, 91B0, 9230, 9240, 92A0, 92D0, 9320, 9340, 9520, 9540
4a	22	1410, 3140, 3150, 3170, 3260, 3280, 3290, 4030, 5330, 6220, 6310, 6410, 6420, 91B0, 91E0, 9240, 92A0, 92B0, 92D0, 9330, 9340, 9560
4b	21	3150, 3170, 3260, 3280, 3290, 4030, 4090, 5210, 5230, 6220, 6310, 6410, 6420, 91B0, 91E0, 92A0, 92D0, 9230, 9240, 9330, 9340
4c	32	1310, 1410, 1420, 1430, 1510, 1520, 3140, 3150, 3160, 3170, 3250, 3260, 3280, 3290, 5210, 5330, 6110, 6170, 6210, 6220, 6420, 6430, 7210, 7220, 91F0, 9240, 92A0, 92D0, 9340, 9540, 9560

^{a75} singular habitat types in the EC Directive across systems

Spanish types of herbaceous communities included in the EU Habitat Directive

The following is a list of 13 natural grassland vegetation types included in the Habitat Directive and represented in Spain (third objective). The IEEP (2007) reported a list of 26 grassland habitats included in the Directive, which depend on extensive agricultural practices (extensive grazing). The 13 Spanish types represent 50% of this list. There are great similarities with Italy (see next tier). Of these 13 codes, 11 are also represented in Italy, but codes 6140 and 6160 are not, while code 6150 is represented in Italy but not in Spain. Similarly, some grassland-related codes such as 5420 (*Sarcopoterium spinosum phryganas*) and 5430 (Endemic *Phryganas* of the *Euphorbio-Verbascion*) are represented in Italy and Greece, but not in the Iberian Peninsula (only 5430 is represented in the Balearic Islands).

61 Natural grasslands

6110. Calcareous Karstic or basophilus of *Alyso-Sedion albi* (*)

Biogeographical regions: M and AL (Mediterranean and Alpine)

Corresponding code in the Spanish Atlas of Habitat: 511010, 511020

Representative species: *Sedum album*, *S. gypsicola*, *S. sediforme*, *Saxifraga tridactylites*, *Hornungia petraea*, *Arenaria serpyllifolia*, *Arabis recta*, *Campanula erinus*, *Velezia rigida*, *Linaria micrantha*

Distribution: Iberian range and SE mountains

6140. Pyrenees pastures of *Festuca eskia* on siliceous soils

Biogeographical regions: AT and AL (Atlantic and Alpine)

Corresponding code: 514010, 514020

Representative species: Commons: *Festuca eskia*, *Jasione laevis*, *Erigeron alpinus*, *Campanula scheuchzeri*

Pyrenees: *Ranunculus pyrenaicus*, *Gentiana alpina*, *Veronica bellidioides*

Cantabrian: *Luzula caespitosa*, *Agrostis tileni*, *Thymelaea dendrobryum*

Distribution: Upland (over 1600 m) Cantabrian and Pyrenees

6160. Iberian pastures of *Festuca indigesta* aggr. on siliceous soils

Biogeographical regions: M, AL

Corresponding code: 516010, 516020, 516030, 516050

Representative species (endemic of restricted areas):

Central Iberian ranges: *Armeria bigerrensis*, *Hieracium vahlii*

Cantabrian range: *Agrostis tileni*, *Armeria duriaei*, *Androsace cantabrica*.

Sierra Nevada: *Festuca clementei*, *Erigeron frigidus*, *Artemisia granatensis*

Distribution: Upland pastures in the Central, Iberian and Sierra Nevada and, partially, Cantabrian ranges.

6170. Alpine and sub-alpine pastures under calcareous soils

Biogeographical regions: M, AT, AL

Corresponding code: 517110, 517120, 517210, 517310, 517320, 517510, 517520, 517530

Representative species:

Pyrenees and Cantabrian ranges: *Sesleria albicans*, *Trifolium thalii*, *Poa alpina*

Cantabrian range: *Festuca burnatii*

Iberian, Central and Betic ranges: *Poa ligulata*, *Koeleria vallesiana*

Distribution: Upland pastures dominated by *Kobresia myosuroides* and *Festuca gautieri* in the Cantabrian and Pyrenees and *Festuca hystrix* in the Iberian, Bética and Central ranges.

62. Seminalural pastures in dry soils with facies of shrubs

6210. Seminalural pastures of *Festuco-Brometalia* on calcareous soils

Biogeographical regions: M, AL, AT

Corresponding code: 521210, 521220, 521310

Representative species: *Bromus erectus*, *Brachypodium rupestre*, *Helictotrichon cantabricum*, *Satureja alpina*, *Carduncellus mitissimus*,

Potentilla montana, *Seseli cantabricum*, *S. montanum*, *Phyteuma orbiculare*, *Anthyllis vulneraria*.

(*) Some orchids such as of genus *Ophrys*, *Orchis*, *Dactylorrhiza*

Distribution: Submediterranean climate on 1000-1800 m in the Cantabrian, Pyrenees and Iberian ranges

6220. Mediterranean dry grasslands, sub-steppic graminaceous and annuals of *Thero Brachypodietea* (*)

Biogeographical regions: M, AT, AL

Corresponding code: 522010, 522020, 522030, 522040, 522050, 522060, 522070, 522080.

Representative species: Numerous endemic species of the genus *Arenaria*, *Chaenorhinum*, *Campanula*, *Asterolinum*, *Linaria*, *Silene*, *Euphorbia*, *Minuartia*, *Rumex*, *Odontites*, *Plantago*, *Bupleurum*, *Brachypodium*, *Bromus* and *Stipa*. In the W part of Spain, *Poa*, *Aira*, *Vulpia*, *Anthoxanthum*, *Trifolium*, *Tuberaria*, *Coronilla*, *Scorpiurus*, and *Ornithopus* are also present. In the most arid areas of the SE, *Stipa capensis* and endemic species of *Limonium*, *Filago*, *Linaria*, etc are present. On gypsum soils, *Campanula fastigiata*, *Ctenopsis gypsophila* and *Clypeola eriocarpa* are present.

Distribution: Mediterranean and submediterranean mountains and plains including the driest areas of Atlantic and Pyrenean regions

6230. Herbaceous formations of *Nardus stricta* in siliceous upland pastures (*)

Biogeographical regions: M, AL, AL

Corresponding code: 523010, 516040

Representative species: *Polygala vulgaris*, *Carex panicea*, *Festuca rivularis*, *F. iberica*, *Luzula multiflora* subsp. *congesta*, *L. campestris*, *Euphrasia willkommii*, *E. hirtella*, *Campanula herminii*, *Danthonia decumbens*, *Gentiana acaulis*, *G. alpina*, *Potentilla erecta*, *Pedicularis sylvatica*, etc. In cervunales (Spanish) of N Spain also appear *Carex leporina*, *C. pilulifera*, *C. pallescens*, *Festuca nigrescens*, *F. paniculata* (subsp. *spadicea* and *paniculata*).

In Sierra Nevada, the endemic richness is higher with *Festuca paniculata* subsp. *longiglumis*, *Potentilla nevadensis*, *Ranunculus acetosellifolius*, *R. demissus*, *Agrostis nevadensis*, *Armeria splendens*, etc.

Distribution: Siliceous mountains of Iberia. Acid soils with humidity (cervunales o borreguiles in Spanish).

63. Open sclerophyllous forest with natural pastures (*dehesas*)

6310. *Evergreen Quercus* spp.

Biogeographical regions: M

Corresponding code: 531010, 531020

Representative species and associations: See previous section.

Distribution: W and SW part of Spain and border with Portugal. Present in acid or neutral soils, with low organic-matter content.

64. Humid natural pastures with tall grasses

6410. Poor nutrient soils with permanent humidity of *Molinion caeruleae*

Biogeographical regions: M, AT, AL

Corresponding code: 541010

Representative species: *Molinia caerulea*, *Juncus acutiflorus*, *J. effusus*, *J. inflexus*, *Epipactis palustris*, *Dianthus deltoides*, *D. superbus*, *Peucedanum carvifolia*, *Cirsium tuberosum*, *Viola palustris*, etc

Distribution: Mainly in the N and W Spain. In the driest areas, this occasional vegetation type may contain elements of the Eurosiberian region.

6420. Humid Mediterranean pastures of tall grasses, *Molinio-Holoschoenion*

Biogeographical regions: M, AT, AL and MA (Macaronesian, Canary Islands)

Corresponding code: 542010

Representative species of the families *ciperaceae* and *juncaceae* with grasses of the genus *Briza*, *Melica*, *Cynodon*, *Festuca*, *Agrotis*, *Poa*, and other genera as *Orchis*, *Pulicaria*, *Hypericum*, *Euphorbia*, *Linum*, *Ranunculus*, *Trifolium*, *Mentha*, *Galium* etc.

Distribution: Present in almost all the Iberian Peninsula and even Balearic and Canary Islands

6430. Ecotones with forest in humid soils, with organic matter rich soils.

Biogeographical regions: M, AT, AL

Corresponding code: 543110, 543120, 543130, 543210, 543220, 543230, 543240

Representative species: Rich diversity even of Eurosiberian plants in their meridional limits (Bartolomé *et al.*, 2005).

Distribution: Most of Spain, except the central-SW part.

65. Mesophilous pastures

Biogeographical regions: M, AT

Corresponding code: 551010, 721110-721180 and 72119, 7211AO, 7211BO

Representative graminoid species of the genus *Arrhenaterum*, *Trisetum*, *Alopecurus*, *Holcus*, *Agrostis*, *Anthoxanthum*, *Bromus*, *Avenula* with many companion species.

Distribution: Mowing pastures in the midlands (**6510**, corresponding 551010) and upland (**6520**, corresponding to 721110-721180 and 72119, 7211AO, 7211BO) mainly in the Central Pyrenees (Bartolomé *et al.*, 2005).

Italian types associated with grazing activity included in the EU Habitat Directive

In Italy 127 habitats of European interest are represented (Petrella *et al.*, 2005). Among them 12 (11 common with Spain) are characterized by herbaceous communities, to which the comparison between Italy and Spain is referred. In both countries, however, other shrub and scrub communities, not listed below, are potentially affected by grazing use (ie, 4060, 4090, 5110, 5130, 5210, 5230, 5310, 5320, 5330, 5420 and 5430). For each habitat type, the corresponding biogeographical regions, representative taxa (EC, 2003) distribution and category of threat (Petrella *et al.*, 2005) are listed.

61. Natural grasslands

6110*. Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*

Biogeographical regions: Alpine-Continental-Mediterranean

Representative species: *Alyssum alyssoides*, *Arabis recta*, *Hornungia petraea*, *Jovibarba* spp, *Poa badensis*, *Saxifraga tridactylites*, *Sedum* spp., *Sempervivum* spp., *Teucrium botrys*

Distribution: Italian peninsular range

Category of threat: low

6150. Siliceous alpine and boreal grasslands

Biogeographical regions: Alpine

Representative species: *Juncus trifidus*

Distribution: Upland areas in Alps

Category of threat: low

6170. Alpine and sub-alpine calcareous grasslands

Biogeographical regions: Continental-Mediterranean

Representative species: Alps and locally northern and central Apennines: *Dryas octopetala*, *Kobresia myosuroides*, *Gentiana nivalis*, *Gentiana campestris*, *Alchemilla conjuncta*, *Alchemilla flabellata*, *Anthyllis vulneraria*, *Astragalus alpinus*, *Aster alpinus*, *Draba aizoides*, *Globularia nudicaulis*,

Helianthemum nummularium subsp. *grandiflorum*, *Helianthemum oelandicum* subsp. *alpestre*, *Pulsatilla alpina* subsp. *alpina*, *Phyteuma orbiculare*, *Astrantia major*, *Polygala alpestris*.

Distribution: Upland areas in Alps, Apennines and Sicily mainly on alkaline soils.

Category of threat: low

62. Semi-natural dry grasslands and scrubland *facies*

6210. Semi-natural dry grasslands and scrubland *facies* on calcareous substrates (*Festuco-Brometalia*) (* important orchid sites)

Biogeographical regions: Alpine-Continental-Mediterranean

Representative species: *Anthyllis vulneraria*, *Arabis hirsuta*, *Brachypodium pinnatum*, *Bromus inermis*, *Campanula glomerata*, *Carex caryophyllea*, *Carlina vulgaris*, *Centaurea scabiosa*, *Dianthus carthusianorum*, *Eryngium campestre*, *Koeleria pyramidata*, *Leontodon hispidus*, *Medicago sativa* subsp. *falcata*, *Ophrys apifera*, *O. insectifera*, *Orchis mascula*, *O. militaris*, *O. morio*, *O. purpurea*, *O. ustulata*, *Polygala comosa*, *Primula veris*, *Sanguisorba minor*, *Scabiosa columbaria*, *Veronica prostrata*, *V. teucrium*, *Bromus erectus*, *Fumana procumbens*, *Globularia elongata*, *Hippocrepis comosa*, *Adonis vernalis*, *Euphorbia seguierana*, *Festuca valesiaca*, *Silene otites*, *Stipa capillata*, *S. joannis*.

Distribution: Sub-Mediterranean, continental and oceanic climate in the Alps and along the whole Italian peninsula.

Category of threat: low

6220*. Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*

Biogeographical regions: Alpine-Continental-Mediterranean

Representative species: *Brachypodium distachyum*, *B. retusum* (*Thero-Brachypodietea*, *Poetea bulbosae*, *Lygeo-Stipetea*).

Distribution: Mediterranean and sub-Mediterranean climate throughout the Italian peninsula, Sicily and Sardinia.

Category of threat: low

6230*. Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and sub mountain areas, in Continental Europe)

Biogeographical regions: Alpine-Continental-Mediterranean

Representative species: *Antennaria dioica*, *Arnica montana*, *Campanula barbata*, *Carex ericetorum*, *C. pallescens*, *C. panicea*, *Festuca ovina*,

Galium saxatile, *Gentiana pneumonanthe*, *Hypericum maculatum*, *Hypochoeris maculata*, *Lathyrus montanus*, *Leontodon helveticus*, *Leucorchis albida*, *Meum athamanticum*, *Nardus stricta*, *Pedicularis sylvatica*, *Platanthera bifolia*, *Polygala vulgaris*, *Potentilla aurea*, *P. erecta*, *Veronica officinalis*, *Viola canina*.

Distribution: Mountain and sub-mountain areas in the Alps and the Apennines

Category of threat: low

63. Sclerophyllous grazed forests (dehesas)

6310. Dehesas, with evergreen *Quercus* spp.

Biogeographical regions: Mediterranean

Representative species: *Quercus suber*, *Q. ilex*, *Q. coccifera*.

Distribution: South Italy, Liguria, Sicily and Sardinia on acid soils with low organic-matter content

Category of threat: middle

64. Semi-natural tall-herb humid meadows

6410. *Molinia* meadows on calcareous, peaty or clayey-siltladen soils (*Molinion caeruleae*)

Biogeographical regions: Continental-Mediterranean

Representative species: *Molinia caerulea*, *Dianthus superbus*, *Selinum carvifolia*, *Cirsium tuberosum*, *Colchicum autumnale*, *Inula salicina*, *Silaum silaus*, *Sanguisorba officinalis*, *Serratula tinctoria*, *Tetragonolobus maritimus*; *Viola persiciflora*, *V. palustris*, *Galium uliginosum*, *Cirsium dissectum*, *Crepis paludosa*, *Luzula multiflora*, *Juncus conglomeratus*, *Ophioglossum vulgatum*, *Inula britannica*, *Lotus uliginosus*, *Dianthus deltoides*, *Potentilla erecta*, *P. anglica*, *Carex pallescens*.

Distribution: from the lowland to the mountain belt in Northern and Central Italy

Category of threat: middle

6420. Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*

Biogeographical regions: Alpine-Continental-Mediterranean

Representative species: *Scirpus holoschoenus*, *Agrostis stolonifera*, *Galium debile*, *Molinia caerulea*, *Briza minor*, *Melica cupanii*, *Cyperus longus*, *Trifolium resupinatum*, *Schoenus nigricans*, *mairii*, *Juncus maritimus*, *J. acutus*, *Asteriscus aquaticus*, *Hypericum tomentosum*, *Inula viscosa*, *Oenanthe pimpinelloides*, *O. lachenalii*, *Eupatorium cannabinum*,

Prunella vulgaris, *Pulicaria dysenterica*, *Tetragonolobus maritimus*,
Orchis laxiflora, *Succisa pratensis*, *Silaum silaus*, *Sanguisorba officinalis*,
Serratula tinctoria, *Genista tinctoria*, *Cirsium monspessulanum*, *Senecio*
doria, *Dorycnium rectum*, *Erica terminalis*, *Euphorbia pubescens*.

Distribution: present in almost all the Italian peninsula in Sicily and in Sardinia
in wet areas

Category of threat: high

6430. Hydrophilous tall herb fringe communities of plains and of the montane to
alpine levels

Biogeographical regions: Alpine-Continental-Mediterranean

Representative species: *Glechoma hederacea*, *Epilobium hirsutum*, *Senecio*
fluviatilis, *Filipendula ulmaria*, *Angelica archangelica*, *Petasites hybridus*,
Cirsium oleraceum, *Chaerophyllum hirsutum*, *Aegopodium podagraria*,
Alliaria petiolata, *Geranium robertianum*, *Silene dioica*, *Lamium album*,
Lysimachia punctata, *Lythrum salicaria*, *Crepis paludosa*; montane to
alpine levels: *Aconitum lycoctonum*, *A. napellus*, *Geranium sylvaticum*,
Trollius europaeus, *Adenostyles alliariae*, *Peucedanum ostruthium*,
Cicerbita alpina, *Digitalis grandiflora*, *Calamagrostis arundinacea*,
Cirsium helenioides.

Distribution: Most of Italy, locally in the South and Sicily, not present in
Sardinia

Category of threat: middle

65. Mesophile grasslands

6510. Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)

Biogeographical regions: Continental-Mediterranean

Representative species: *Arrhenatherum elatius*, *Trisetum flavescens* subsp.
flavescens, *Pimpinella major*, *Centaurea jacea*, *Crepis biennis*, *Knautia*
arvensis, *Tragopogon pratensis*, *Daucus carota*, *Leucanthemum vulgare*,
Alopecurus pratensis, *Sanguisorba officinalis*, *Campanula patula*,
Leontodon hispidus, *L. nudicaulis*, *Linum bienne*, *Oenanthe pimpinelloides*,
Rhinanthus lanceolatus, *Malva moschata*, *Serapias cordigera*.

Distribution: from the lowland to the mountain belt throughout the Italian
peninsula and North-Eastern Sicily

Category of threat: middle

6520. Mountain hay meadows

Biogeographical regions: Alpine-Continental

Representative species: *Trisetum flavescens*, *Heracleum sphondylium*, *Astrantia major*, *Carum carvi*, *Crepis mollis*, *C. pyrenaica*, *Bistorta major*, *Silene dioica*, *S. vulgaris*, *Campanula glomerata*, *Salvia pratensis*, *Centaurea nemoralis*, *Anthoxanthum odoratum*, *Crocus albiflorus*, *Geranium phaeum*, *G. sylvaticum*, *Narcissus poeticus*, *Malva moschata*, *Trollius europaeus*, *Pimpinella major*, *Muscari botryoides*, *Lilium bulbiferum*, *Thlaspi caerulescens*, *Viola tricolor* subsp. *subalpina*, *Phyteuma halleri*, *P. orbiculare*, *Primula elatior*, *Chaerophyllum hirsutum*, *Cirsium heterophyllum*.

Distribution: Northern part of the peninsula; scattered in centre, south and Sicily.

Category of threat: middle-high.

Greek types of herbaceous communities in the EU Habitat Directive

In Greece, 109 habitats of European interest are represented (Dafis *et al.*, 2001). Among them 8 (all common with Spain and Italy) are characterized by herbaceous communities. As in Spain and in Italy, however, other shrub and forest communities, not listed below, are potentially affected by grazing use (i.e. 4060, 4090, 5110, 5130, 5210, 5230, 5310, 5320, 5330, 5420 and 5430). For each herbaceous habitat type, representative taxa, distribution and category of threat (Dafis *et al.*, 2001; Dimopoulos *et al.*, 2006) are presented.

61. Natural grasslands

6110*. Rupicolous calcareous or basophilic grasslands of the *Alyso-Sedion albi*

Representative species: *Poa timoleonis*, *Festuca* sp., *Arenaria leptoclados*, *Muscari botryoides*, *Sedum urvillei*, *Ornithogalum* sp.

Distribution: infrequent and rare (high mountains of central and northern Greece)

Category of threat: high

6170. Alpine and sub-alpine calcareous grasslands

Representative species: *Festuca varia*, *Daphne oleoides*, *Astragalus angustifolius*, *Stipa pennata*, *Festuca* sp., *Thalictrum minus*, *Teucrium montanum*, *Eryngium creticum*, *Thymus longicaulis*, *Thymus sibthorpii*, *Juniperus communis* ssp. *nana*

Distribution: infrequent and rare (high mountains of central and northern Greece)

Category of threat: high

62. Semi-natural dry grasslands and scrubland facies

6210. Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)

Representative species: *Festuca valesiaca*, *Geranium rotundifolium*, *Chrysopogon gryllus*, *Thymus longicaulis*, *Alyssum murale*, *Bornmullera tymphaea*, *Festuca* sp., *Brachypodium pinnatum*, *Artemisia campestris*

Distribution: widespread and scattered (almost everywhere but mainly in northern Greece)

Category of threat: medium-high

6220*. Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*

Representative species: *Aira elegantissima*, *Brachypodium distachyon*, *Brachypodium retusum*, *Aphanes minutiflora*, *Bromus hordeaceus*, *Euphorbia rigida*, *Filago gallica*, *Hypochaeris glabra*, *Linum strictum*, *Lotus halophilus*, *Ornithopus compressus*, *Trachynia distachya*, *Stipa capensis*, *Tuberaria guttata*, *Vulpia ciliata*, *Bellis annua*, *Andropogon distachyos*, *Plantago albicans*, *Vulpia myuros*, *Trifolium campestre*, *Myosotis rammosissima*, *Asphodelus ramosus*, *Convolvulus althaeoides*, *Hyparrhenia hirta*, *Bituminaria bituminosa*, *Anthemis rigida*, *Plantago weldenii*, *Polypogon maritimus*, *Echinops spinosissimus*, *Glaucium flavum*, *Geranium molle*, *Asphodelus fistulosus*, *Aphanes arvensis*, *Bromus madritensis*, *Anthemis arvensis*, *Carlina corymbosa* ssp. *graeca*, *Atractyllis cancellata*, *Piptatherum coerulescens*, *Centaureum tenuiflorum*, *Crepis multiflora*, *Hirschfeldia incana*, *Leontodon tuberosus*, *Hainardia cylindrica*, *Silene colorata*, *Trifolium stellatum*, *Anthemis chia*, *Catapodium rigidum*, *Arenaria leptoclados*, *Hypochaeris achyrophorus*, *Filago pygmaea*, *Galium murale*, *Lagurus ovatus*, *Misopates orontium*, *Parentucellia latifolia*, *Tolpis barbata*, *Scandix australis*, *Scorpiurus muricatus*, *Sherardia arvensis*, *Avena barbata*, *Plantago coronopus*, *Trifolium scabrum*, *Psilurus incurvus*, *Echium arenarium*, *Cynosurus echinatus*, *Hyoseris scabra*, *Filago eriocephala*, *Erodium cicutarium*, *Polycarpon tetraphyllum*, *Bromus sterilis*, *Malva parviflora*, *Erodium malacoides*, *Trifolium nigrescens*.

Distribution: widespread and scattered (almost everywhere in low altitudes)

Category of threat: medium

6230*. Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and sub mountain areas, in Continental Europe)

Representative species: *Nardus stricta*, *Thymus longicaulis*, *Plantago holosteam*, *Anthoxanthum odoratum*, *Festuca varia*, *Hieracium*

hoppeanum, *Alopecurus gerardii*, *Carex kitaibeliana*, *Festuca peristerea*,
Festuca hirtoraginata, *Thymus praecox*

Distribution: widespread and scattered (high mountains of mainland)

Category of threat: high

64. Semi-natural tall-herb humid meadows

6420. Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*

Representative species: *Oenanthe pimpinelloides*, *Scirpus holoschoenus*, *Juncus effusus*, *Lathyrus neurolobus*, *Plantago lanceolata*, *Polypogon monspeliensis*, *Dittrichia viscosa*, *Equisetum ramosissimum*, *Trifolium resupinatum*, *Hydrocotyle vulgaris*, *Bolboschoenus maritimus*, *Ranunculus ficaria*, *Imperata cylindrica*, *Juncus acutus*, *Ranunculus marginatus* var. *trachycarpus*, *Saccharum ravennae*, *Schoenus nigricans*, *Elymus elongatus*, *Aeluropus littoralis*, *Juncus heldreichianus*, *Lythrum junceum*, *Carex distans*, *Orchis laxiflora*, *Carex divisa*, *Mentha pulegium*, *Poa trivialis*, *Rumex conglomeratus*, *Trifolium repens*, *Ranunculus velutinus*, *Rubus sanctus*, *Hordeum marinum*, *Briza minor*, *Juncus articulatus*, *Trifolium lappaceum*, *Phragmites australis*, *Apium nodiflorum*, *Carex otrubae*, *Alopecurus myosuroides*, *Brachypodium sylvaticum*, *Cyperus longus*, *Equisetum telmateia*, *Festuca pratensis* ssp. *pluriflora*, *Mentha spicata*, *Lotus preslii*, *Anagallis tenella*, *Cynanchum acutum*, *Carex divulsa*, *Lotus angustissimus*, *Anagallis tenella*, *Isolepis cernua*, *Athyrium filix-femina*, *Carex flacca* ssp. *serrulata*, *Carex hispida*, *Hainardia cylindrica*, *Rumex pulcher*, *Eleocharis multicaulis*, *Serapias lingua*

Distribution: widespread and scattered (almost everywhere in wetlands)

Category of threat: high

6430. Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels

Representative species: *Bellis perennis*, *Cirsium appendiculatum*, *Cirsium arvense*, *Galega officinalis*, *Mentha aquatica*, *Trifolium resupinatum*, *Agrostis capillaris*, *Cirsium vulgare*, *Juncus effusus*, *Lysimachia punctata*, *Veratrum album*, *Deschampsia caespitosa*, *Geum coccineum*, *Eriophorum latifolium*, *Geum rivale*, *Orchis palustris*

Distribution: infrequent and rare (high mountains of central and north Greece)

Category of threat: very high

65. Mesophile grasslands

6510. Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)

Representative species: *Alopecurus pratensis*, *Trisetum flavescens*, *Cichorium intybus*, *Sanguisorba officinalis*, *Knautia arvensis*, *Tragopogon pratensis*, *Daucus carota*, *Campanula patula*, *Leontodon hispidus*, *Oenanthe pimpinelloides*, *Malva moshata*

Distribution: infrequent and rare (mountains of central and north Greece)

Category of threat: medium-high

DISCUSSION

We have dealt with two main issues on this research. The first was to identify relevant LSGS in Spain, Italy and Greece, unveiling their main economic and environmental values as well as constraints. In this case, the abandonment trend is widespread, although not homogeneous and appearing at different time scales. Second, we have assessed a general pattern of influence of the abandonment trend on successional trajectories, target vegetation types and plant species. Again, grazing is congenial with species richness but we also found plant species adapted to post-grazing succession.

The abandonment trend, because it was felt simultaneously across countries, must have had a common cause, but this trend was not even of the same magnitude within one country. In Spain, for example, the *dehesa* system is much more alive than traditional livestock production in the central Pyrenees or in the cereal-sheep system. We can shed some light from comparative analysis or we must rely on differential diagnosis because of the futility to look for non contingent empirical regularities (Rodrik, 2004). In any case, a major task ahead is to devise a framework of evolution diagnostic and policy support for European LSGS in danger of abandonment.

The European Council regulation (RDP, 2005), adopted in September 2005, is aimed at devising the Rural Development Policy (RDP) for the period 2007-2013. Three implementing regulations by the Commission followed in 2006, including the Community Strategic Guidelines (CSG) and timetable for submission of regional and national Rural Development programs. One important and conditional issue for implementing the RDP, and included in drafts of the Strategic Guidelines, is the identification of the areas where the use of EU support will create the most value added at the EU level. The EU Commission is aimed at articulating the RD plans around three ECON-ECOL axes, but space scale of Axis 2 (ECOL) are current schemes such as Natura 2000, LFA (mountain and handicap areas), and agro-environment. How these schemes are going to be articulated with socioeconomic criteria of sustainability such as competitiveness (Axis 1) or diversification of the rural economy (Axis 3) is hard to imagine. If all these schemes are maintained, in their present form, the simplification process, one main and required goal of the new RDP, will be at risk. Our collaborative

research may contribute to identify HNV farmland in Europe and to simplify the current policy framework by singling out a large part of HNV areas around LSGS.

The lumping of a range of LSGS with distinctive climatic, structural, social and technical frameworks under the rubric of sectoral operations can perhaps be portrayed as “policy clarity”, but it tramples on the real constraints behind many of the causes of unsustainability. Even within one country, the same production sector can be operating under very different structural and social conditions. In Spain, for example, the extensive sheep sector differs greatly from the Pyrenees to the cereal-sheep system and from this latter to the *dehesa*. Traditional sectoral economic accounting and official records would provide little insight on the environmental and social effects of the grazing operation. It is only at the large scale of grazing systems that the social fabric of rural life can be identified and proper environmental and economic analysis carried out. This is why the first phase of identification and description of LSGS, carried out in the Presentation section, is of paramount importance.

Local livestock breeds have become endangered in many parts of the world (FAO, 1999). Focusing this trend on Europe, 35% of goats and 25% of sheep autochthonous breeds are endangered (Bertaglia *et al.*, 2007) and this fact is associated with the abandonment of extensive husbandry in marginal areas. Indigenous livestock breeds have been widely referred in this research as being important indicators of biodiversity in Mediterranean extensive systems. The maintenance of important herbaceous communities is linked by coevolution to grazing behaviour and habits of these breeds. The status of conservation of some indigenous breeds of mountain livestock in Spain has been reported (Sierra, 1996; Sánchez, 2002; Esteban, 2003). The first author has evaluated the environmental assets and potential risks of Spanish indigenous livestock breeds. Moreover, the European Econogene project has evaluated the status of farmed animal breeds within the European Union (Bertaglia *et al.*, 2007).

Most Spanish ruminant livestock are still raised under extensive conditions. A proportion of cattle and goats are kept for milk production, where intensive production is dominant. Ecological significance of indigenous breeds presented many examples of adaptation to their environments and shaping of these environments under the influence of extensive grazing. Some Spanish indigenous breeds are consolidated within their specific environment but many others, more local breeds, are under danger of extinction. This problem attracts less social attention than the extinction of the Iberian lynx, notwithstanding the importance of the latter.

Interactions between local livestock breeds and their environment under Mediterranean conditions take many forms. Many annual herbaceous and shrubby species produce hard-seeds as a defence against harsh climatic conditions. Germination of these seeds is favoured by ruminant digestion (Robledo *et al.*, 1993), as is the case

of the *albaida* (*Anthyllis cytisoides*) and subterranean clover (*Trifolium subterraneum*). Indigenous livestock grazing in Mediterranean highlands is probably the best way to control shrubby invaders and lessening the virulence of uncontrolled mountain fires (Carrizosa *et al.*, 1995).

Monserrat (1996) indicated the presence of *Festuca* aggr. *indigesta* as a target species for highland Iberian range pastures. The presence of this specie is linked to grazing habits of the Camerana indigenous cattle breed that hampers shrubby invaders such as *Calluna vulgaris*. *Festuca* aggr. *indigesta* may also soften the effect of avalanches. Similarly, Monserrat and Fillat (2004) linked the maintenance of alpine pastures in the Pyrenees, dominated by *Festuca nigrescens* subsp. *microphylla*, to the grazing use by wild animals and indigenous livestock breeds of high mobility and well adapted by coevolution.

As to the second tier of discussion, the EU public support to LSGS and general handicapped areas is awarded and socially justified under the assumption that these systems may deliver environmental assets (externalities) not properly factored in farm prices. It is widely recognized that a large part of European natural values are concentrated in these LFA (Brouwer *et al.*, 1997) and, consequently, this function is stressed as main argument in support of government intervention, justifying taxpayers' money (Verhulst *et al.*, 2004; Newton, 2004; Strijker, 2005). However, quantitative analyses on the effects of extensive grazing on ecological functions, and particularly on vegetation changes, over a wide range of European environments are lacking, with the few of them (Naveh and Whittaker, 1979; Marriot *et al.*, 2004), showing little consideration for the underlying social causes of land use changes.

Frequently, ecological data on vegetation changes take a big footstep on the geophysical factors such as climate and soil conditions and much less on grazing treatments. This is the consequence of a traditional European divergence between agronomic and ecological disciplines (Oglethorpe and Sanderson, 1999), while in the USA traditional range management relies heavily on vegetation succession (Stoddart *et al.*, 1975) and state-and-transition models (Briske *et al.*, 2005). Land uses and vegetation types (states) can be the subject of different management alternatives (transition paths) in order to reach an overhauling of sensible environmental and socio-economic assets. State-and transition models suits managed landscapes (Papanastasis and Chouvardas, 2005). Selection and analysis of proper alternatives is a main task. This research job has dealt more with description and analysis of the current state of Mediterranean LSGS than with prescriptive paths. Transitional models for overhauling managed LSGS are probably required.

The global effects of grazing on vegetation changes and species richness can be congenial, neutral or uncongenial and species-specific data and statistical tests concerning the abundance of species under various grazing treatments and stages of post-grazing

succession are required. Sensible grazing management can only be derived from proper knowledge of vegetation succession and species-specific reaction to grazing treatments (Oksanen *et al.*, 2006). From our case studies on successional trajectories, one general pattern may arise. Intra habitat diversity, as judged by species richness, was higher under extensive grazing than under transitional shrubby overgrown stages induced by abandonment. On the other hand, we have found plant species adapted to post-grazing succession and, in this case, interspersed areas with different grazing intensity or grazing use may provide higher inter habitat diversity (case studies of Galicia and León in Spain, the latter in Table 4). In the *dehesa* system, *Poa bulbosa* is adapted to sheep grazing (Rivas Goday and Ladero, 1970), while in the calcareous sierras of SE Spain, short grass *Brachypodium retusum* is susceptible to medium-high grazing intensity (Navarro *et al.*, 2006).

The abandonment trend of traditional grazing areas is a common phenomenon across the three countries, but the time-scale of the process diverged between countries, between systems and even within particular systems of one country. On a global scale of greater, to lower incidence the LSGS of Italy, Spain and Greece can be rated. However, large differences were found in Italy between the Alps and Sardinia or, in Spain, between the central Pyrenees and the *dehesa* systems. Even within systems, we found a wide array of situations that may allow the study of the abandonment process at the system scale. In the Pyrenees, for example, we may find old cereals fields with a history of more than 50 years of abandonment together with semi-abandoned grasslands or intensive irrigated meadows more near the villages (Reiné *et al.*, 2004; Vicente-Serrano *et al.*, 2004; Pueyo and Begueria, 2007). This gives way to a wide range of early- to late-transitional vegetation stages (Molinillo *et al.*, 1997). In the *dehesa* system, the abandonment trend is less acute, but we found open and well-managed stands and also abandoned ones, with under-story encroachment of *Cistus*-dominated communities.

In this research we have valued the relationship between grazing and biodiversity, the latter being rated as species richness and target vegetation types. However, other ecological functions can be affected by extensive grazing or by post-grazing successional trajectories on LSGS. Questions such as the consequences of present land use trends on soil and water quality, erosion control, wildfires' risk, seed bank activity or even climate change are barely addressed on Mediterranean LSGS. The only system where these lines of research are operative is in the central Pyrenees. Vicente-Serrano *et al.* (2004) have related vegetation cover and biomass increments in the central Pyrenees with consequences of abandonment and the corresponding revegetation process, with a close relationship between vegetation activity and increments of the mean annual temperature. Molinillo *et al.* (1997) found better control of sediments' yield and runoff under a dense shrub cover of *Genista scorpius*. Reiné *et al.* (2004) found that extensive-

managed grasslands are more useful in terms of regeneration from the soil seed bank than intensive-managed ones. Thus, restoring species adapted to nutrient-rich conditions from the seed bank was unlikely. Alados *et al.* (2007) analyzed self-organized spatial patterns of vegetation in alpine areas of the central Pyrenees with different grazing pressures. Species richness and diversity declined significantly with an increase of grazing intensity because few species were able to colonize empty space of bare soil. Finally, Lasanta *et al.* (2006) proposed an alternative management scenario of conversion of shrubby invaders to grasslands. The strategy increased significantly the available pastoral resources and landscape diversity and diminished the fire risk without affecting soil erosion or landscape fragmentation. In the Mediterranean basin of Southern France, Debussche *et al.* (2001) compared the successional changes in *Quercus pubescens* woodlands after 18 years of grazing cessation with previously undisturbed plots, and found a time-lag between undisturbed plots and post-grazing succession. In both, grassland species decreased and forest species increased, to a lower rate in the post-grazing succession due to a slow decline linked to previous grazing.

In others Mediterranean LSGS such as in Gran Paradiso National Park (Western Alps sector of Italy), Laiolo *et al.* (2004) have surveyed the status of breeding birds under long-term abandonment of pastoral activities. Avian diversity of common species invaded abandoned pastures under shrub encroachment but, conversely, less common bird species of open habitat, which benefited from grazing, were mostly confined to pure grasslands at higher altitudes. Overall, in terms of birds' conservation, large-scale grazing abandonment resulted detrimental to avian diversity.

Concerning grazing systems and conservation of biodiversity, it must be stressed the importance of an adequate knowledge of the species and habitat specific impacts of grazing regimes. Moreno Saiz *et al.* (2003) revised the adverse pressures stated for 8300 populations of the 478 most threatened vascular plants species (Bañares *et al.*, 2003) in Spain (Canary and Balearic Islands included). The most frequently recorded threat, affecting to 38% of the populations, was overgrazing. Trampling was also a highly rated threat, quoted for 30% of the populations. Although similar trends had been indicated in previous assessments of the Spanish threatened flora (Domínguez *et al.*, 1996; Gómez Campo, 2002), this is at present the best-documented evaluation of the situation. It can be argued, however, that many species supposedly affected by overgrazing are plant of small size, shade-intolerant and poor competitors, so they probably need some kind of disturbance, grazing included, preventing the competitive displacement by late-successional types of vegetation (Díaz *et al.*, 2007). In any case, the main issue is that even extensive grazing requires a good knowledge on its impacts on conservation targets, for properly establishing the management plans and regulations compatible with conservation (Bagella and Caria, 2010; Salis *et al.*, 2010).

The last referred report (Díaz *et al.*, 2007) includes a review on the effects of agricultural practices (grazing included) on habitat types and species of Annexes I and II of the EU Directive (92/43/CEE) present in Spain. From 217 plant species evaluated, 10% are considered as grazing-dependent and 16% more as favoured by some grazing pressure, although being sensitive even to moderate overgrazing. Others (42%) are considered sensitive to grazing by browsing, trampling or eutrophication, and for the remaining 32%, grazing impacts are not identified or considered not to be significant. With respect to the 116 terrestrial types of habitats of EU significance and present in Spain, around 11% are clearly grazing-dependent and two-thirds of them can be considered sensitive to grazing pressure, although a majority are currently under some kind of grazing management (see Table 5). Specific research on the requirements of habitats and species and their relationship with stocking regimes is needed, particularly on the relations between grazing regimes and vegetation structure, vegetation structure and species recruitment, and the interactions among livestock and species regeneration patterns.

In a more global European assessment carried out in the LACOPE project (Kaule, 2006), it was shown that out of 175 evaluated bird species included in the Annex I of the Bird Directive, about one third (57 species) were considered as positively influenced by extensive grazing. The same research evaluated the effect of extensive grazing in 201 out of the 218 habitat types included in the EU Directive. Out of these, 58 habitat types were assessed as depending on grazing for at least 25% of the countries for which assessment was done. They concluded, "Grazing is not a kind of management which is suitable for all or at least more of European priority species. Nevertheless, grazing seems to be able to support species diversity and target species for nature conservation in Europe to a comparable large extent".

This research has shown the derelicts state of many Spanish, Italian and Greek LSGS and the inability to deliver potential environmental, social and economic functions under the current abandonment trend. In previous research, we have addressed some of the underlying causes of this situation. Unprofitability, social fragility and insensible policy support schemes are some internal and external causes of concern (Caballero *et al.*, 2007, 2008; Caballero and Gil, 2009). Main drivers of change such as intensification of crop and livestock production techniques or de-structuring of family business and co-operative forms of production are seen as unavoidable, even within the scientific community (Zorita, 2001), justifying the declining trends of LSGS. The paradox of this situation is that, at the same time, intensive forms of production are criticized on the grounds of low energy and protein efficiency rates and environmental and health hazards (McMichael *et al.*, 2007). This research has explored some environmental ramifications of the current situation, rather than the potential technological innovations and business models that

can contribute to change the current trend. There is not sound scientific evidence that the LSGS are intrinsically uneconomic or socially fragile. We have a few examples of how on-the-system management alternatives can derive economic and environmental assets in particular LSGS (Caballero, 2007, 2008) or some examples of traditional European LSGS culturally rooted and socially supported (Riseth, 2006). At the end, LSGS may require particular environmental, business and social models for investigation and policy support within a differential farming category.

Paradoxically, there is much less information on economic performance of LSGS than the recorded for their natural values; most available information is recorded at local level. Campos Palacín (1993) and Plieminger and Wilbrand (2001) have surveyed the environmental and economic values of the *dehesa* system. The latter authors stressed problems of intensification such as free-range grazing at high stocking levels and crossbreeding with high-performance breeds as causes of concern. Caballero *et al.* (2007) reported quantitative economic and social data for the cereal-sheep system indicating that some 40-50% of sheep farmers were operating with losses (without subsidies) in the year 2003. The wording comments of some collaborative experts on the LACOPE project, as explanations of their choices, indicated that promotion and marketing of indigenous livestock products is a promising line of research and support in pursuit of economic and social sustainability because, indirectly, it may also favour the social fabric of the systems (Caballero *et al.*, 2008). One example of this path to rural development can be the *dehesa* system. Iberian pig production and processing are quality assets with a strong emphasis on consumers' awareness. Environmental, economic and social validation of management alternatives within particular LSGS is a first phase of a research agenda. Only after this phase, institutional, legal or policy schemes can be devised and implemented in support of best management practices. Top-down devised institutional and policy reforms are aimed to be flawed if the people's views are ignored and economic consequences not clearly stated. Economic reforms should thus make institutional and policy reforms easier to bring about.

Affluent consumers and taxpayers are more and more prone to the fancies of fad diets and prepared foods. However, they relate this trend to the new alchemist of food and cuisine, not to primary food production on the cultural rooting of rural life. This connection is lacking in the chain of food to people. This connection can only be apparent if, progressively, consumers get deep into the subtleties of rural systems, where original food ingredients are produced. Many inhabitants of today's big cities have some rural background, and often a slight wistfulness with it. This can be exploited to strengthen the links with rural life and farmers. Simultaneously, LSGS farmers may look inwards for reforms but outwards as main path to development. Many of the investigated LSGS, such as those Spanish systems involved in the transhumance during the Mesta times,

were closely linked with the economic and social life of the region. This is in striking contrast with present, more sedentary forms of production linked to the less favoured rougher terrain and depopulated areas. Livestock farmers in these areas are losing the war of empathy and boosting communication with the rest of the population, which is of paramount importance in present times.

INTERPRETIVE SUMMARY

This research work showed how inter-disciplinary ECOL and ECON criteria might and should be applied if we are to choose the large scale of extensive livestock systems. Only at this scale can weaknesses and strengths be unveiled and sensible policy schemes devised and implemented, including rural development plans. Technological innovations and social improvements can be applied to systems, not to vegetation units, and natural values and biodiversity are an effect, and not a cause, of proper grazing management and cultural traditions. Although worked at the landscape scale, landscape suggests something scenery and static, but beauty and biodiversity are by-products of the way a landscape works and is worked. LSGS bring works to the landscape by renewing the life cycles of nature and man. Thus, protection schemes should be aimed at systems, not only at landscapes.

Large Scale Grazing Systems (LSGS) in the three Mediterranean countries analyzed are endowed with natural values, including a high diversity of vegetation types and species linked to grazing use. Understanding the vegetation dynamics of these communities and regeneration requirements of particular species are important issues for regulating grazing use in a sensible way. We have unveiled the cultural rooting of Mediterranean LSGS. If unmanaged, the paths toward potential vegetation take hold, but these paths usually represent lower environmental and socioeconomic values. If managed intensively, we also lose environmental values. This finding is hardly surprising as these values are historically rooted in more open and managed landscapes.

This research also illustrated the actual sustainability risk of these extensive systems. This fragile state of European LSGS in the Mediterranean region is mainly related to socioeconomic concerns. Notwithstanding the diversity in physical environments, many external experts expressed concern for the abandonment threat and related some common causes such as poor economic performance and lack of social cohesion and family turnover assurance. Under the present trends, much more research is needed to clear what would be the main effects on a wider range of nature values. Most data, showed changes to vegetation types of lower biodiversity value, endangered autochthonous livestock breeds, risk of quality assurance of some indigenous livestock products, and a depopulation trend of the most remote areas. Mediterranean LSGS in the three countries

are where the break between old and new is worst. Mending their downward trend means going back, not to reconstruct history but to pick up the thread from it.

This research may have contributed to identify LSGS as differential environmental and business models, for which specific schemes of policy support should be devised and implemented. The effects of agricultural intensification on the environment have been widely addressed in a defensive way, and mitigation techniques (e.g., direct sowing, precision agriculture, improved irrigation) implemented, but much less the potential assets of LSGS and the effects of grazing abandonment in extensive systems. This is a task for ecologists, while agronomists must look on how to restore the economic and social life of many European LSGS. An interdisciplinary task lies ahead.

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SISTEMAS DE PASTOREO Y BIODIVERSIDAD EN ÁREAS MEDITERRÁNEAS: ESPAÑA, ITALIA Y GRECIA

RESUMEN

En los sistemas de pastoreo interaccionan las leyes naturales y la influencia humana afectando a distintos aspectos funcionales con efectos a gran escala. En este estudio se analizan los efectos sobre los tipos de vegetación y las especies con interés de conservación de acuerdo con las directivas europeas. Frecuentemente, estos sistemas se localizan en las áreas europeas menos favorecidas y representan un importante reservorio de valores naturales. Sin embargo, hasta la fecha no se ha realizado un inventario a escala europea sobre su localización, perfil descriptivo, estado actual y tendencias. Los principales sistemas de pastoreo de tres países mediterráneos (España, Italia y Grecia) se han revisado en cuanto a su distribución biogeográfica y sus perfiles funcionales con un marco metodológico común, y se ha analizado la evolución de sus tipos de vegetación y especies principales, a partir de una extensa revisión bibliográfica y de consultas sistematizadas a un panel de expertos. Se argumenta que, tanto la intensificación convencional como el abandono, pueden conducir a tipos de hábitats de inferior valor natural. El análisis comparado indica una variabilidad acusada en los sistemas descritos respecto a su estado actual de transición y estrategias de pastoreo, y una tendencia común al abandono que difiere en sus escalas temporales y espaciales, pero que conlleva como pautas generales la expansión de especies leñosas y la reducción de la diversidad florística. En sistemas pastorales concretos, la relación pastoreo-biodiversidad no es unívoca y en buena parte se relaciona con la distribución espacial y temporal del pastoreo y con su intensidad, y cualquier evaluación debe ser referida a especies y hábitats particulares. Las principales estrategias de pastoreo tradicionales (movilidad de los animales, diversidad de recursos pastorales, instituciones reguladoras del pastoreo) se encuentran, con frecuencia, poco operativas, siendo necesario un diagnóstico particular de cada sistema de pastoreo para establecer rutas de transición y esquemas de ayudas que faciliten su regeneración.

Palabras clave: Descriptiva de sistemas de pastoreo, trayectorias sucesionales de la vegetación, tipos de hábitats, especies con interés de conservación, pastos de alto valor natural, desarrollo rural.