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Mediterranean grazing systems and plant biodiversity

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Abstract

Mediterranean grazing systems are biological structures considered hot spot of biodiversity. *Dehesa* is a Mediterranean agroforesty grazing system, where grassland and grazing management can affect the pasture biodiversity. With the aim to study the effect of grazing system typologies (GS) and grassland management (GM) on pasture biodiversity a study was carried out in six livestock farms located into the *Dehesa* landscape of Sardinia Island. Farms were characterized for some structural and economic traits. Sampling areas were located in thirteen pastures of farms characterized by different GS (beef and dairy cattle and dairy sheep), and by different type of GM (short, medium and long rotation with forage crops). The effects of GS and GM were evaluated on pedological characteristic, forage production and botanical composition of pasture. Chemical fertility parameters of soil, herbage mass and balance between botanical families in pasture were influenced by GS. GM affected herbage mass only the first year. The thirteen pastures were, also, clustered in three groups based on their floristic affinities. The groups didn't show differences in species richness and Shannon diversity index. Group 3, which includes two pasture of beef cattle farm, showed a strongly lower grazing value than group 1 and 2. Canonical correspondence analysis pointed out that GS and soil organic carbon were the factors that mostly have affected the assemblage composition of groups.

A) Mediterranean grazing systems and plant biodiversity

1 Mediterranean grazing systems

1.1 Grazing system features

Mediterranean grazing systems are biological structures that arise from the interactions between natural resources and human behaviour. The environmental conditions and geographic, climate and edaphic constraints affect these systems, to characterise the different types of agro-pastoral societies that are based on breeding livestock as a traditional activity. With concentration of the rainfall during the cold season and total absence during the hot summer, the Mediterranean climate strongly influences herbage availability for pasture, with large intra-annual and inter-annual variability. The vegetation model consists of herbs, bushes and trees that can coexist, to contribute to the feeding of domestic and wild animals (Olea et al., 1997). The *dhesa* habitat belongs to this model, with a dominance of evergreen oak (*Quercus suber, Quercus ilex, Quercus coccifera),* and where the herbaceous canopy has been preserved by pastoral management. *Dhesa* is widespread in the western Mediterranean area and in Italy it is found mainly in the Tyrrhenian region and on the Islands. Here, the animal production systems are dominated by small ruminants, mainly sheep and goats, as these can better exploit the unfavourable areas, whereas cattle-breeding is limited (Porqueddu et al., 1998).

The Mediterranean grazing systems, which are mainly included in marginal areas, are considered as hot spots of biodiversity. They are characterised by high natural value, with the presence of many different plant and animal species. They also have extensive management in terms of low stocking rates and units of mineral fertilisation, with few areas cultivated with crops and high grazing of the natural pastures. Moreover, they have low productivity in terms of the pasture biomass production.

1.2 Grazing systems in the social context

In Mediterranean grazing systems, the rural population often live under harsh environmental and social conditions (Caballero et al., 2009). Often there is an unsuitable infrastructure and a lack of social services provided for subsistence agriculture, with the consequent limitations to the use of the natural resources. The recent increasing crisis of the 'livestock sector' has been hit hard by the economic structure of the dairy farms, and especially for those with a low income. In this context, young farmers are not particularly attracted by the extensive livestock operations and continued family management of marginal farms cannot be assured. Indeed, abandonment is currently the most apparent threat. In Sardinia, grazing systems were developed from ancient and original cultures, and they were based on community land management with a diffuse sense of land possession without formal legal ownership.(Brigaglia, 1982). The farm system has been based on family labour and it rarely turned to casual labour. Most of the livestock farms have dairy sheep or meat cattle, and their small dimensions limit the competitiveness of their products in the agriculture market.

The main types of habitats are cultivated pastures on the plains, and Mediterranean forests or open bushland in the hilly and mountainous areas (Caballero et al., 2009); the secondary types are often characterised by low forage yield in the cold season, which forces livestock farmers to integrate grassland production with hay and feedstuff, thus increasing management costs. In more recent years, the continual lowering of the price of milk and its derived products, and the higher costs of supplements, fertilisers and energy, have strongly reduced farmers gains and the economical sustainability of their grazing systems. European Union (EU) subsidies (such as for organic farms or animal welfare) and regional financial support (low grazing fees for public lands) have contributed to keeping grazing systems viable, even if under low-income conditions (Caballero et al., 2009). In spite of this, in Sardinia the farm livestock conditions are also made worse by the inability to repay bank loans taken out in previous years, which has lead some shepherds to stop their traditional breeding activities and to sell their herds. The main consequence of this is the abandonment of lands previously used for agriculture, with the disappearance of potential economic, environmental and social values (Caballero, 2007).

This reduction in traditional pastoral activities has lead to increased unemployment, with repercussions on the social balance of these regions. This loss of the agro-pastoral culture has effects not only on society, but also in the landscape, with the vanishing of the old patterns and elements, such as stone walls, bush fences, vernacular architecture and trees (Pungetti, 1995). Moreover, the lower human control over the rural areas is linked with higher risk of fires. The custom of using fire in Sardinia is ancient, and is typical of agro-pastoral systems; it aims to create new areas for pasture and to improve soil fertility. But uncontrolled and recurrent fires have a deep impact on the natural vegetation, leading shrub colonisation with a prevalence of xerophilous evergreens (Aru et al., 1982). Over the last few years, the rise of protected areas and the greater preventive measures have led to a reduction in fires events and to the reconstitution of the previous natural conditions.

1.3 Opportunities and perspectives

Mediterranean grazing systems need to improve their sustainability in a way that fits in with the current requirements of the agricultural market. Sustainability can be considered a concept that comprises different aspects: (economic) viability, resilience and adaptability, bearable work conditions, and environmental integrity (Roggero et al., 1996). Economic sustainability is the main aspect for survival of the pastoral systems, and all others factors are closely linked to this. In general, the aim should be to replace external farm inputs with internal farm resources. This objective relates to sustainable systems that are based on the rational use of local environmental resources, particularly concerning animal feed, and land and energy resources. Adaptation to local environmental conditions is a fundamental issue. In the Mediterranean area, local forage ecotypes have often proven to be more productive and persistent than commercial varieties.(Franca et al., 1995). The animal feeding systems are a sub-system of farming systems and they cannot be considered as independent of them (Roggero et al., 1996). Cereal crop-stock integration, which is widespread in Mediterranean grazing systems, is an example, where the farm crop model is closely linked to the animal production cycle. The flexible use of local landraces of oats and barley in relation to the seasonal weather provides good quality forage in winter and stubble for grazing in summer, which fits with the energy requirement patterns of dairy sheep; in spring, some fields of these crops are closed to animals so as to produce grain or hay, or they can be continuously grazed in most dry seasons.

The multiple use of land resources is a key factor towards increasing the income of the farmer, with the aim being to achieve an acceptable quality of life. The primary activity of livestock production should be integrated into the other activities that are more consistent with the socio-economic context (Roggero et al., 1996). Over the last few years, EU subsides and regional financial support have given farmers new opportunities to develop complementary activities to their breeding livestock. For instance, rural tourism for visits to farms, knowing the productive processes, and the high quality of agro-foodstuffs can be profitable ways for the future. The grasslands and rangelands of Mediterranean farms are characterised by a high level of biodiversity, providing the opportunity to create a 'reservoir' for rare species, or for landscapes of value that can be exploited. The EU decoupling rule (N°. 1783/2003) frees farmers from land cultivation and has had an important impact on farm management in terms of achieving lower-input agriculture. This regulation links full payments of direct aid to farmers who respect some rules that appear easily acceptable to Mediterranean livestock farms, especially those concerning the maintenance of agricultural land in "good agricultural and environmental conditions". The requirements for maintenance of a minimum soil cover, for arable stubble management, for the protection of permanent pasture, and for appropriate machinery use are often realised in extensive management systems. Minimum tillage and sod seeding, agronomic techniques that preserve soil erosion, the saving of energy are being more and more used as part of cereal and forage-crop management. The modernisation of traditional working systems is another point that is being pursued. Suitable milking machines, cooling tanks, and sheepfolds are very important for human working conditions, animal welfare and the quality of production. Livestock products can be discriminated according to the characteristics of quality and production systems.

Finally, it is fundamental to follow the objectives for the exploitation of renewable energy resources. Financial support for photovoltaic power plants and biogas systems is increasing. All of the secondary products that derive from agricultural activities (wood, stubble, manure) can be used as energy sources, thus reducing the external input. The rational use of all of the available natural energy resources can improve grazing systems and provide economical sustainability for the great weight that the energy requirements have on the farm balance; moreover, an ecological agricultural system is more integrated into the environmental context of the rangelands and is more friendly towards the maintenance of biodiversity.

2 Plant biodiversity in European Mediterranean grasslands.

2.1 Ecosystem services

Conservation of wild biodiversity systems provides a important set of 'ecosystem services', ecological processes and functions that sustain and improve human well being (Daily, 1997). The main types of ecosystem services of note are:

- the ability to provide food, animal feed and other useful products, such as timber and herbal medicines;
- the ability to regulate or interact with particular environmental processes, such as flooding, soil erosion and carbon sequestration;
- the supporting services, such as soil formation and pest control;
- the cultural services, which relate to aesthetic or recreational assets.

A diverse range of organisms contribute at various levels to the set of biological processes that are involved in ecosystem services: e.g., bacteria in nutrient and organic matter cycles; insects in pollination and phytophagous regulation; birds in seed dissemination.

Biodiversity is a generic term that includes variations at intra-species, genetic, species and ecosystem diversity levels (Purvis and Hector, 2000); these cannot be reduced only to a number that represents the species richness. The identity and variety of the elements of ecosystems should be considered, along with the physical organisation and ecological and evolutionary processes that they involve (Aguiar, 2005). Moreover, several recent studies have shown greater plant productivity and nutrient retention associated with higher plant-species diversity of pastures (Hector et al., 1999).

Biodiversity is the basis of agriculture, and has enabled agricultural systems to develop and evolve according to the current conditions. Therefore biodiversity and agriculture are strongly interrelated, and if biodiversity is fundamental for agriculture, agriculture can also contribute to conservation and sustainable use of biodiversity. Agricultural biodiversity includes all of the components of biological diversity that characterise agricultural systems: the variety and genetic variability of the animals, plants and micro-organisms that are necessary to sustain the key functions of the agro-ecosystem (Convention on Biological Diversity, 2000). Agricultural biodiversity is the result of interactions between the environment, genetic resources and farmer activities. Climate, chemical and physical factors, and the pedological structure, have determining effects on biodiversity; the environmental context can really balance the contrast of the effects of human activities on genetic resources, which can restore the native conditions in the long term.

Grassland 'land use' includes all human activities that involve grasslands, and these range from agricultural practices to urbanisation. The different grassland ecosystems have been subjected to particularly intense pressures for the production of food and fibre, with high levels of extinction of grassland species. At the local level, some species can become extinct and others can colonise and invade landscapes (Aguiar, 2005).

The large-scale grazing systems of Europe include grasslands of marginal areas where the habitat conditions arise from interactions between extensive agro-pastoral activity and the natural resources (Caballero et al., 2009). These systems are characterised by high structural diversity at different levels, which provides a broad range of habitat with diversity of species and communities (Hopkins et al. 2006). This diversity, which characterises the regional and social identity, allows the development of different types of 'unique landscapes' that, in turn, can allow exploitation of the tourism potential from an ecological point of view.

2.2 Grasslands management

Agricultural biodiversity has also been strongly shaped and developed through the farmer management of both grasslands and arable areas. Generally, where intensive livestock production is practised, biodiversity has been greatly reduced. The effects of pesticides and herbicide applications, seeding and mechanical tillage have all contributed to this biodiversity loss.

Nitrogen fertilisation changes the processes of denitrification, leaching and rate of extinction and colonisation in the plant communities (Aguiar, 2005). Some studies have highlighted that nitrogen addition can lead to a reduction in plant diversity in grasslands with a dominance of a few species, and to the suppression of many other species (Silvertown, 1980; Tilman, 1987). Phosphorus fertilisation increases the presence of legumes in pastures, changing the natural floristic balance of the plant species (Salis et al., 2008). A supply of manure can also influence the species composition of grasslands, through its high nutrient content, the importation of seeds, and the smothering of the sward by liquid or solid manure (Plantureux et al., 2005).

Grazing management influences the canopy structure and types, along with the number of plant species of grasslands (Sitzia et al., 1997). Defoliation arising from the frequency and timing of grazing and the cutting of the canopy can disturb the flowering and seeding cycles of plant species, which can change their balance in pastures. A study of south Mediterranean pastures has highlighted higher species richness under continuous cattle grazing, as compared to pasture subjected to seasonal grazing (Sternberg et al., 2000). Moreover, botanical functional groups composed of hemicryptophytic species show less variability with grazing types when compared with functional groups with annual species. However, across a wide variation of grazing regimes and climate conditions, the plant communities were shown to be adapted to grazing with a relatively small amplitude of change, due to the long history of human association (Sternberg et al., 2000). In another study, Moreno Saiaz et al. (2003) indicated that the most frequently recorded threatened species, which include 38% of the Spanish plant population, were due to overgrazing (Caballero et al., 2009). In some marginal areas of Sardinian pastoral systems, overgrazing has led to the prevalence of non-palatable species, with a consequent decrease in the grazing value of the rangeland; pastures that are characterised by the presence of native forage species with high agronomic value that are grazing tolerant (such as subclover or burr medic) maintain a better botanical composition. In any case, in grazing systems, an adequate knowledge of the specific impacts of the species and the habitat on grazing regimes is fundamental to conservation of plant biodiversity (Caballero et al., 2009). Moreover, livestock can have major effects on the propagation of some species, as germination of hard seeds is favoured by the ruminant digestion effects on seed coats.

Land use and land cover changes can be considered as the main causes of loss of grassland biodiversity. The two main types of land cover that have affected grassland biodiversity are cropping and forestry (Aguiar, 2005). Cropping changes the plant biomass both above and below the ground, and therefore this also changes the organic matter content of the soil. Cultivation of forage crops, with the introduction of new species, can change the pattern of biodiversity of pastures, although it is not clear whether in extensive systems this can lead to the disappearance of the native species. Conversion to forest leads to important changes in grassland ecosystems, such as a lower soil pH and a different chemical composition of the soil, although the lower sunlight availability due to the forest canopy can also decrease the plant biodiversity and herbaceous productivity.

When carried out with inappropriate machines, mechanic operations can deeply compromise the vegetation cover of the rangelands. In several pastures of marginal lands, the clearing of low, deep and sloped ground of the shrubby and woody vegetative cover, and the following tillage has led to soil erosion and degradation (Porqueddu et al. 1998).

Generally, low-intensity livestock farmlands can support considerable botanical diversity as they can provide habitats for faunal groups and a range of ecosystems and socio-economic functions (Hopkins and Holtz, 2006). The important EU-funded LACOPE project, which provides an ecological and economic study of seven European large-scale grazing systems, has highlighted that extensive grazing is a neutral effect, and that it can sometimes be helpful for maintenance of the European level of biodiversity (Caballero, 2007).

Abandonment is the most extreme form of decreased land use. This can arise as a consequence of the moving of the farmers to better lands, or sometimes of the suspension of their pastoral activities. This gives way to a wide range of early to late transitional vegetation stages (Molinillo et al., 1997). In the abandoned forest, it is frequent to have encroachment of the undercover of Cistus-dominated communities, while Caballero et al. (2009) and Peco et al. (2006) did not note differences in species richness after abandonment of a *dehesa* pasture in Spain. On the other hand, in another study in the uplands of Sardinia, Farris et al. (2009) indicated a decline in the plant species numbers five years after abandonment. Furthermore, species of conservational concern and phytogeographical interest tend to disappear, to be replaced by species that are widespread in the Mediterranean area.

2.3 EU biodiversity policies

Over the last 20 years, the EU environmental and rural development policies have been aimed at integrating nature and landscape conservation values in agricultural lands. In 1992, the United Nations Conference on Environment and Development approved the text of the 'Convention on Biological Diversity'. In this document, each contracting Member State undertakes to "develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity", and to integrate this "into relevant sectoral or cross-sectoral plans, programmes and policies." (CBD, 1993).

Also in 1992, the Habitat Directive of the European Commission established a European ecological network known as *Natura 2000*, which comprises special areas of conservation (Site of Community Interest; SCI) that can be designated by Member States according to the provisions of this Directive. At the moment, in Europe and Italy the surface included in the Natura 2000 network is about 13% and 14% of the terrestrial area, respectively (EEA, 2009). Sardinia has 15% of its territory included as SCIs and 74% of these lands belong to woodland areas (AA.VV. PSR, 2007). The Rural Development Plan for Sardinia for 2007-2013 provides an allowance for farmers for the application of the Habitat Directive and financial support for agro-systems that are biodiversity friendly, meaning low pesticide use and crop rotation. Moreover, this plan provides payments to increase the environmental value of forestry ecosystems with sustainable management.

Baldock et al. (1993, 1995) introduced the concept of high nature value farmland (HNVF), which includes 'hot spots' of biodiversity in rural areas, which are usually characterised by extensive farming practices (EEA, 2004). Even if a definitive map of the EU HNVFs still does not exist, preliminary studies show that in Sardinia, such areas cover roughly 50% of the used agricultural area, which is mainly represented by grazed grasslands and rangelands (AA.VV. PSR, 2007).

In 2003, in the Kyiv resolution of biodiversity, the European ministries for the environment recognised that biological and landscape diversity provides goods and services to humankind, and they have agreed to identify all of the HNVF areas and to take the appropriate conservation measures (UN/ECE, 2003). Moreover, the resolution provides for increasing public and private financial investment in integrated biodiversity activities in Europe.

Overall, the reform of the Common Agricultural Policy (CAP), which was adopted in 2003 by the agriculture minister of the EU, decoupled farmer subsides from production and linked them to respect of the environmental and to food safety and animal welfare standards. Moreover, providing these requirements to keep all farmland in good agricultural and environmental condition aims to support extensive systems and the conservative of biodiversity.

3 References

Aguiar M.R. (2005). Biodiversity in grasslands. current changes and future scenarios. In Reynolds S.G. and Frame J. (Ed.), Grasslands: Developments, Opportunities, Perspectives. Science Publishers Inc, Enfield, USA, 261-280.

Aru A., Baldaccini P., Melis R.T., Camarda I., Ballero M., Bocchieri E., De Martis B. (1982). Ricerche pedologiche, floristiche e fenologiche sui pascoli del bacino del Rio S'AcquaCallenti (Villasalto, sardegna sud orientale).Bollettino della SSSN, vol 21, 199-283.

AA.VV. (2007). PSR - Programma di Sviluppo Rurale 2007-2013. Reg. (CE) N.1698/2005, 50-58.

Baldok D., Beaufory G., Bennet G., Clark J. (1993). Nature conservation and new directions in the common agricultural policy. IEEP London.

Baldok D., Beaufory G., Clark J. (1995). The nature of farming. Low intensity farm systems in nine European countries. Report IEEP/ WWF/JNRC, London/Gland/Peterborough, UK.

Brigaglia M. (1982). Il paesaggio agrario. In: Le opere e i giorni. Contadini e pastori nella Sardegna tradizionale,. Eds. F. Manconi; G. Angioni . Silvana Editoriale. Milano (Italy), 160-203.

Caballero R. (2007). High nature value (HNV) grazing systems in Europe: a link between biodiversity and farm economics. The Open Agriculture Journal, 1, 11-19.

Caballero R., Fernàndez-Gonzàlez F., Badia R.P., Molle G., Roggero P.P., Bagella S., D'Ottavio P., Papanastasis VP., Fotiadis G., Sidiropoulou A., Ispikoudis I. (2009). Grazing systems and biodiversity in Mediterranean areas: Spain, Italy and Greece. Pastos, XXXIX,1, 9-53.

CBD - Convention on Biological Diversity, art.6. (1993).

CBD - Convention on Biological Diversity (2000).COP 5 decision V/5, appendix.

Daily, G. (1997). Nature's services: societal dependence on natural ecosystems. Washington, DC:Island Press.

EEA (2004). High Nature Value farmland – characteristics, trends and policy challenges. EEA, Report N° 1/2004. European Environmental Agency, Copenhagen,. 2-4.

EEA (2009). Natura 2000. European Commission Nature and Biodiversity Newsletter. 27 December 2009,. 8-10.

Farris E., Filigheddu R.,Deiana P., Farris G. A., Garau G. (2010). Short-term effects on sheep pastureland due to grazing abandonment in a western Mediterranean island ecosystem: a multidisciplinary approach. Journal for Nature Conservation, doi: 10.1016/J.Jnc.2009.11.003.

Franca A., Porqueddu C., Roggero PP., Sulas L. (1995). Adattamento e produttività di alcune graminacee da prato e da pascolo in ambiente semi-arido mediterraneo. Rivista di Agronomia 29, 2, 171-177.

Hector, A., Schmid B., Beierkuhnlein C., Caldeira M.C., Diemer M., Dimitrakopoulos P.G., Finn J.A., Freitas H., Giller P.S., Good J., Harris R., Hogberg P., Huss-Dannell K.,Joshi J., Jumpponen A., Korner C., Leadley P.W., Loreau M., Minns A., Mulder C.P.H., O'Donovan G.,Otway S.J., Pereira J.S., Prinz A., Read D.J., Scherer-Lorenzen M., Schulze E.D., Siamantziouras A.S.D., Spehn E.M., Terry A.C., Troumbis A.Y., Woodward F.I., Yachi S., Lawton J.H. (1999). Plant diversity and productivity experiments in European grassland. Science 286, 1123-1127.

Hopkins A., Holz B. (2006). Grassland for agriculture and nature conservation: production, quality and multi-functionality. Agronomy Research 4, 3-20.

Molinillo M., Lasanta T., Garcia-Ruiz J.M. (1997). Managing degraded landscape after farmland abandonment in the central Spanish Pyrenees. Environmental Management, 21, 587-598.

Olea L., Viguera F.J. (1997). Dehesa ecosystem: production and preservation. 9th Meeting of the Mediterranean Sub-Network of the FAO-CIHEAM. Inter-Regional Cooperative Research and Development Network on Pastures and Fodder Crops, 239-246.

Peco B., Sànchez A.M., Azcàrate F.M. (2006). Abandonment in grazing systems: consequences for vegetation and soil. Agriculture, Ecosystems and Enviroment, 113, 284-294.

Plantureux S., Peeters A., Mc Cracken D. (2005). Biodiversity in intensive grasslands: Effects of management, improvements and challenges. Agronomy Research 3, 153-164.

Porqueddu C., Sulas L. (1998). Mediterranean grassland systems. Ecological Aspects of Grassland Management. 17th EGF Meeting, 335-345.

Purvis, A., Hector, A. (2000). Getting the measure of biodiversity. Nature, 405, 212-219.

Pungetti G. (1995). Anthropological approach to agriculture landscape history in Sardinia. Landscape Urban Plane, 31, 47-56.

Roggero P.P., Bellon S., Rosales M. (1996). Sustainable feeding systems based on the use of local resources. Annals of Zootechnology 45, 105-118.

Salis L., Vargiu M. (2008). Influence of mineral fertilization on production and quality of forage in a Sardinian pasture. Biodiversity and Animal Feed. Future Challenges for Grassland Production. 22nd EGF Meeting, 308-310.

Silvertown J. (1980). The dynamics of a grassland ecosystem: botanical equiliubrium in the Park Grass Experiment. Journal of Applied Ecology, 17:491-504.

Sitzia M., Fois N., Porqueddu C., Sulas L., Ligios S. (1997). Effect of dairy sheep grazing management on canopy structure of a mixed sward in the Mediterranean environment. Proc. of Ecological Basis of Livestock Grazing in Mediterranean Ecosystems. W. P. Papanastasis and D. Peter (Eds), 249-253.

Sternberg M., Gutman M., Perevolotsky A., Ungar E.D., Kigel J. (2000). Vegetation response to grazing management in a Mediterranean herbaceous community: a functional group approach. Journal of Applied Ecology, 37, 224-237.

Tilman D. (1987). Secondary succession and pattern of plant dominance along experimental nitrogen gradients. Ecological Monographs, 57, 1898-214. Anthropological approach to agriculture landscape history in Sardinia. Landscape Urban Plane, 31, 47-56.

UN/ECE (2003). Kyiv Resolution on Biodiversity. Fifth Ministerial Conference "Environment for Europe", Kyiv, Ukraine, 21-23/5/2003. Document ECE/CEP 108, 1-7. United Nations, Economic Commission for Europe.

B) Agronomic and managerial characterization of a Dehesa grazing system

Key words: cattle, farm structure, grassland management, livestock management, sheep, Sardinia

1 Introduction

The Mediterranean region is characterised by the presence of a dominant landscape in the rural areas that is known as '*dehesa*' This is an agro-forestry system that is mostly characterised by scattered oak trees where the ground surface is covered by native vegetation, which is dominated by annual herbaceous species (Joffre et al., 1988). In the *dehesa* there is a great variety of herbaceous species, mainly belonging to the grasses and legumes botanical families, with predominance of annual over the limited number of perennial species. (Olea and Viguera, 1997). The whole of these vegetation resources can contribute to the feeding of domestic and wild animals in a multi-productive extensive ecosystem. *Dehesa* is widespread in the western Mediterranean, and mainly in the southwest of the Iberian peninsula (Spain and Portugal), although it is also found in northern Africa, southern France and Greece. In Italy, *dehesa* is common in the Tyrrhenian region and on the islands. The variety of land tenure and land management systems has led to extreme diversity of these agro-sylvopastoral systems (Joffre et al.1991).

On the Iberian peninsula, most of the *dehesa* involves private landholding with family management. The soils are siliceous acidic types, with low fertility; they mostly consist of brown meridian soil that is easily eroded and is poor in nutrients (Olea et al., 1997). Therefore, cultivation is restricted to 20% to 25% of the area, and this consists of grain and green cereals, which are sometimes mixed with vetch (Caballero et al., 2009). The predominant tree species are holm oaks (*Quercus ilex* subsp. *Ballota*), which are found across 80% of the *dehesa*, followed by cork oak (*Quercus suber*) (Gaspar et al., 2008).

Figure 1. Typical landscape of the Iberian *dehesa* system.

This system includes different livestock species, as mainly sheep, beef cattle and Iberian pigs, which are raised for extensive meat and live-animal production (Gaspar et al., 2007). Mixed grazing is common, and acorns are an important feedstuff resource, particularly in the winter season. The use of grazing management that is suited to the capacity of the system or of forest re-growth has conserved the tree stratum, which has increases the efficiency of this system (Coelho, 1992). Most of the livestock systems have zonal variability of pastoral and stubble resources, and they are adapted to various forms of migration (Joffre et al., 1988). Nevertheless, livestock frequently complete their annual cycle without migration. The sheep system is characterised by one lambing every year, in autumn, rotation grazing and long rest period for the rangelands. The maximum feeding requirements correspond to the maximum potential availability of the green grazing resources between mid-autumn and late spring (Joffre et al. 1988).

The Mediterranean islands include a few areas with a *dehesa* landscape. In Sardinia, some extensive farm systems have many traits similar to those that characterise a '*dehesa* type'. Gallura, for instance, is a region that is located in north-eastern Sardinia, where the pastoral activity has shaped a hilly farmland landscape that is characterised by the presence of typical elements, such as stone walls, bush fences and rural buildings. The vegetation here is mainly composed of sclerophilous forests of scattered evergreen oaks (*Q. ilex and Q. suber*) (Caballero et al., 2009) with the ground surface covered by a herbaceous canopy that is dominated by annual species. From the pedological standpoint, Gallura has acid soils on a granite substrata. The livestock species that are bred here are beef cattle, sheep, and less frequently, goats and pigs. However, non-irrigated dairy sheep are the most common livestock farms. On these farms, livestock management provides the use of pastures as mainly feed resources, with variable supplements (hay and feedstuff) in winter, summer and autumn. The main lambing season occurs in November, and more scattered lambing occurs from the end of January to March (Roggero et al., 1996). Milking machines are widespread on these farms, and milk production is mostly processed into cheese.

Beef cattle are present on a few of these farms, whereas suckling-cow management is widespread. In this system, the calves are grown with the mother on pasture until 6-8 months of age, and then they are sold.

One of the main problems here is the inadequate herbage production on the natural pasture during the winter season, when the energy requirements of the flocks are highest. Therefore, in many of these livestock systems, winter cereals and annual forage crops are cultivated in the most favoured areas, and mineral fertilisation is used, for mainly nitrogen and phosphorus. The aim of this study is to analyse the '*dehesa*-type farm system' of a representative area of the Gallura region, with the survey focussed on the different grassland management and grazing systems, and on the characteristic traits of these livestock farms.

2 Materials and methods

This study was carried out during the two-year periods of 2008-09 and 2009-10, in the territory of the Berchidda and Monti municipalities, which are part of the Gallura region (Fig 3). On the basis of the Thornthwaite and Mather parameters, the climate in this area is classified as mesothermal-subhumid (Arrigoni, 2006), with an average annual rainfall of above 585 mm and temperatures ranging from 8 °C (mean January minimum) to 33.5 °C (mean August maximum). The study area is included within the same 'environmental unit' as defined by Blasi et al. (2000). The potential vegetation is represented by neutro-acidophilous cork-oak meso-woods that belong to the association *Violo dehnhardtii-Quercetum suberis* (Bacchetta et al., 2009). Six livestock farms that were considered representative of the Mediterranean extensive grazing systems were selected, and they were studied according to their structural and managerial characteristics: three dairy sheep farms (DS, Sh 1, 2 and 3), one dairy cattle farm (DC, Ca 1, Fig 2), and two beef cattle farms (BC, Ca 2 and 3).

Farmers were questioned regarding the following data:

- farm size, farm workers, number of animals, and stocking rate;
- cultivated crops, agronomic techniques, and pasture management;
- milk and meat income, feed and crop cultivation costs;
- livestock management and feeding.

For each farm, we focused on three different types of grassland management, in relation to the number of years from the last crop establishment (tillage, fertilisation, seeding with forage crops): long rotation, more than 20 years (A); medium rotation, 5 to 10 years (B); short rotation, 2 years (C). The experimental design was unbalanced, as in some of the farms it was not possible to identify all of the types of grasslands. Overall, 14 fields were studied on the six farms. In each field, a pedological profile was carried out, with sampling of the diagnostic horizons for chemical and physical analyses. The soil classification was according to the USDA Soil Taxonomy (USDA Soil Survey Staff, 2006). Laboratory analyses were performed following the "Official methods for the chemical and physical analyses of soil" of the Italian Ministry for Agricultural and Forestry Policies (Violante, 2000; Pagliai, 2001). In the winter of 2009, three 5 m × 5 m fences were randomly positioned in each field. During the spring of 2009 and the autumn–winter–spring of

2009-10, the herb cover was 'treated' with a handheld electric grass mower, to simulate grazing to 2-3 cm, on a strip of 0.1 m × 5.0 m inside and outside of the enclosure cages, to measure the non-grazed herbage mass (H_m) and the grazed herbage on offer (H_o), respectively. The canopy height on each sampling date was also measured by the weighted-disc method. From these data, the pasture growth rate was estimated. Moreover, regression curves between the grass height and the seasonal production of pasture dry matter were investigated. The chemical composition of the H_m (crude protein, CP, neutral detergent fibre, NDF, acid detergent fibre, ADF and acid detergent lignin, ADL) was assessed by near-infrared reflectance spectroscopy (Shenk and Westherhaus, 1994). On three occasions during the grassland vegetative period (spring 2009 and 2010, autumn 2009), forage samples collected inside the cages were partitioned to assess the dry matter (DM) contribution of grasses, legumes, composites and other botanical families.

In 2009, the total energetic requirements (TER) were also estimated on each farm for the herd per year and per hectare, and for the different feed energy sources. These TER were estimated considering the animal requirements for their maintenance, grazing and milk or meat production, and they are expressed as French Feed Units (UFL; INRA 1988; Rossi et al., 1985). The energy offered with supplements was calculated considering the total amount of hay and concentrated feed given to the animals and their energy content in UFL (INRA, 1988). The energy derived from the pasture (herbage) was calculated as the difference between the TER and the supplements offered.

During periods of herbage sampling, the stocking rates and grazing management of the 14 pastures were monitored. The average monthly stocking rate (SR) was calculated in LU $ha^{-1}d^{-1}$ (livestock units per hectare per day). The energy requirements of the animals grazing in each field (excluded supplements taken) were also considered, to estimate the SR energy requirements (SER, UFL $ha^{-1}d^{-1}$). Over the same period (spring 2009, and autumn–winter–spring 2009-10) an overgrazing index (O_i) was calculated, as expressed by the formula O_i = SER/pasture energy offer. O_i values above 1.0 indicated that the pasture was overgrazed, whereas O_i values below 1.0 showed a level of grazing pressure that was lower than the potential productivity of the pasture.

Forage the DM production, botanical composition and grazing parameters, these were analysed with the SAS statistical software package using the GLM

ANOVA procedure within each sampling date. The percentages were transformed into arcsin values; H_m, H_o, as log values because of the strong correlation between the means and variances. An unbalanced CRD split-plot design was used, with the main plots represented by the grazing system typology and the subplots by the grassland management.

Figure 2. Pasture landscape in the dairy cattle farm.

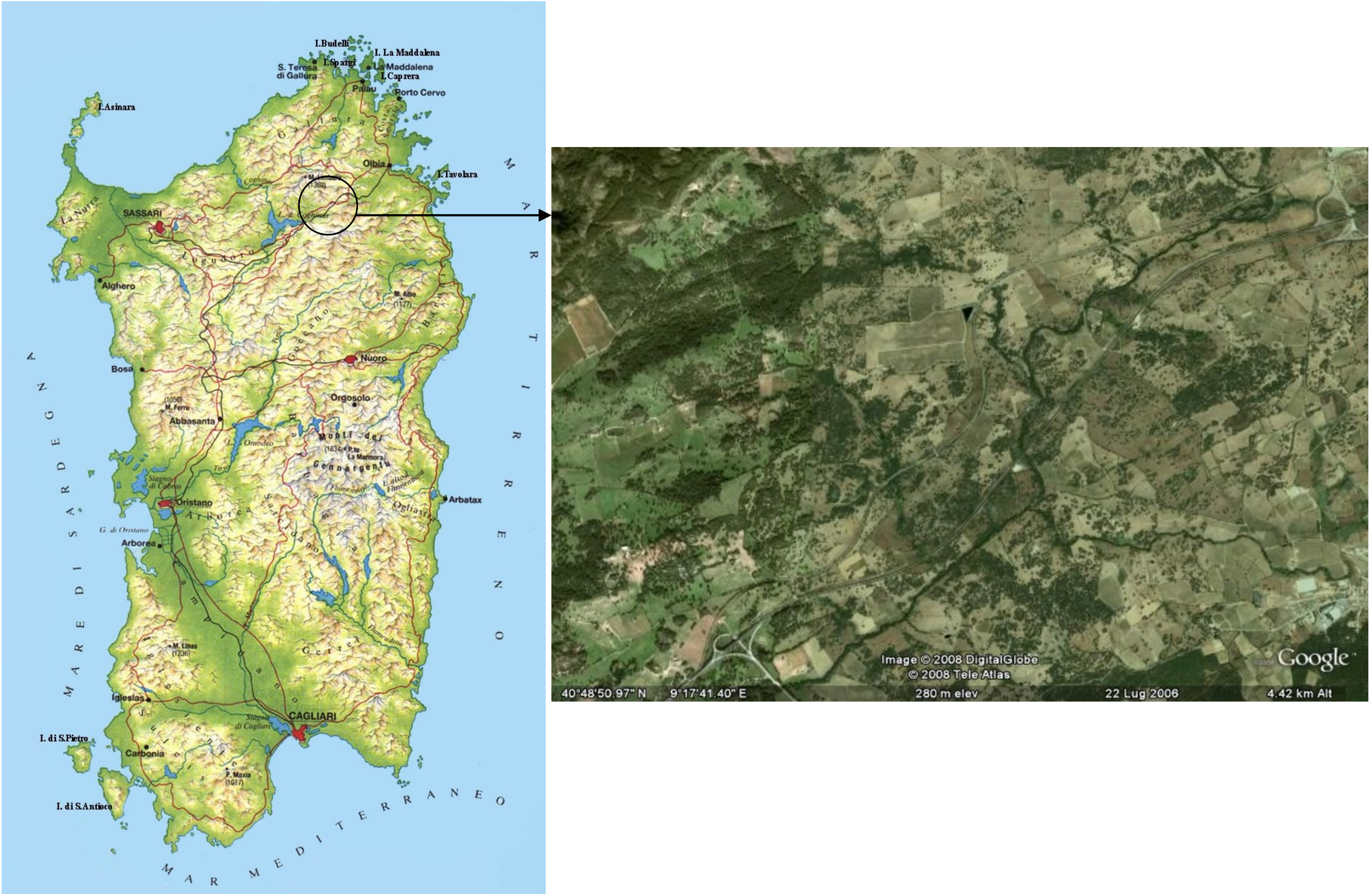

Figure 3. Location of the survey area.

3 Results

3.1 Meteorological trends

Figure 4 shows the data collected from the ARPA (Dipartimento Specialistico Regionale Idroclimatico) meteorological station at Berchidda (290 m a.s.l.). The total annual rainfall from June to May in 2008-09 was 525 mm, and in 2009-10, 905 mm. The seasonal distribution was very variable over the two years. In particular, in the autumn and winter of the second year, the rainfall was twice that in the first year. The temperature trend over the two years was very similar, with the summer average maximum temperature above 30 °C, and the winter average minimum temperature below 5 °C. This last value was 3 °C lower than average.

Figure 5 shows the values for the relative humidity (RH) over the two years of the survey. The level of humidity of the atmosphere and the soil temperature fluctuations are two important factors that can influence the loss of hardseededness in several annual legume species, which can affect their regrowth and persistence in the pasture (Loi et al., 1999; Taylor, 2005). The good presence of legumes in a pasture is an indicator of suitable climatic conditions for the seed softening process.

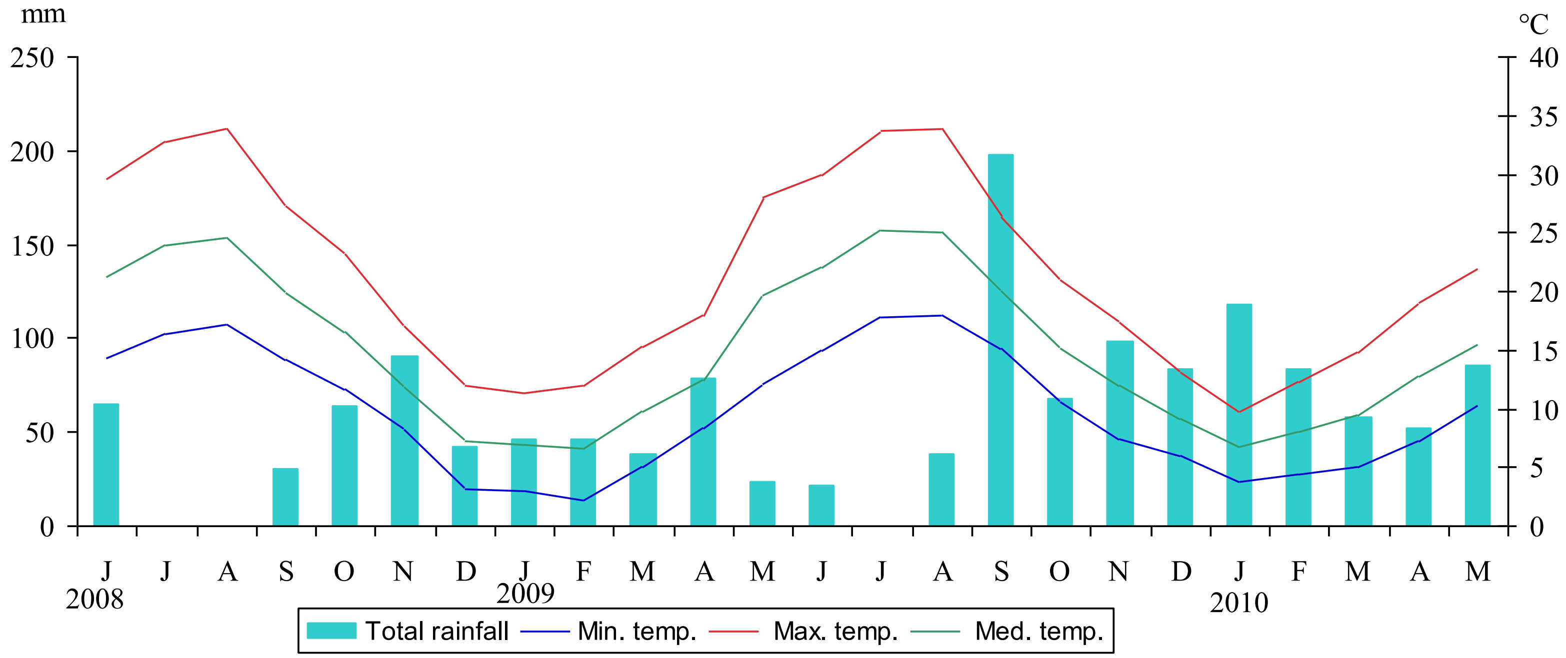

Figure 4. Average minimum, mean and maximum temperatures and total rainfall from June 2008 to May 2010 at the Berchidda meteorological station (ARPA data).

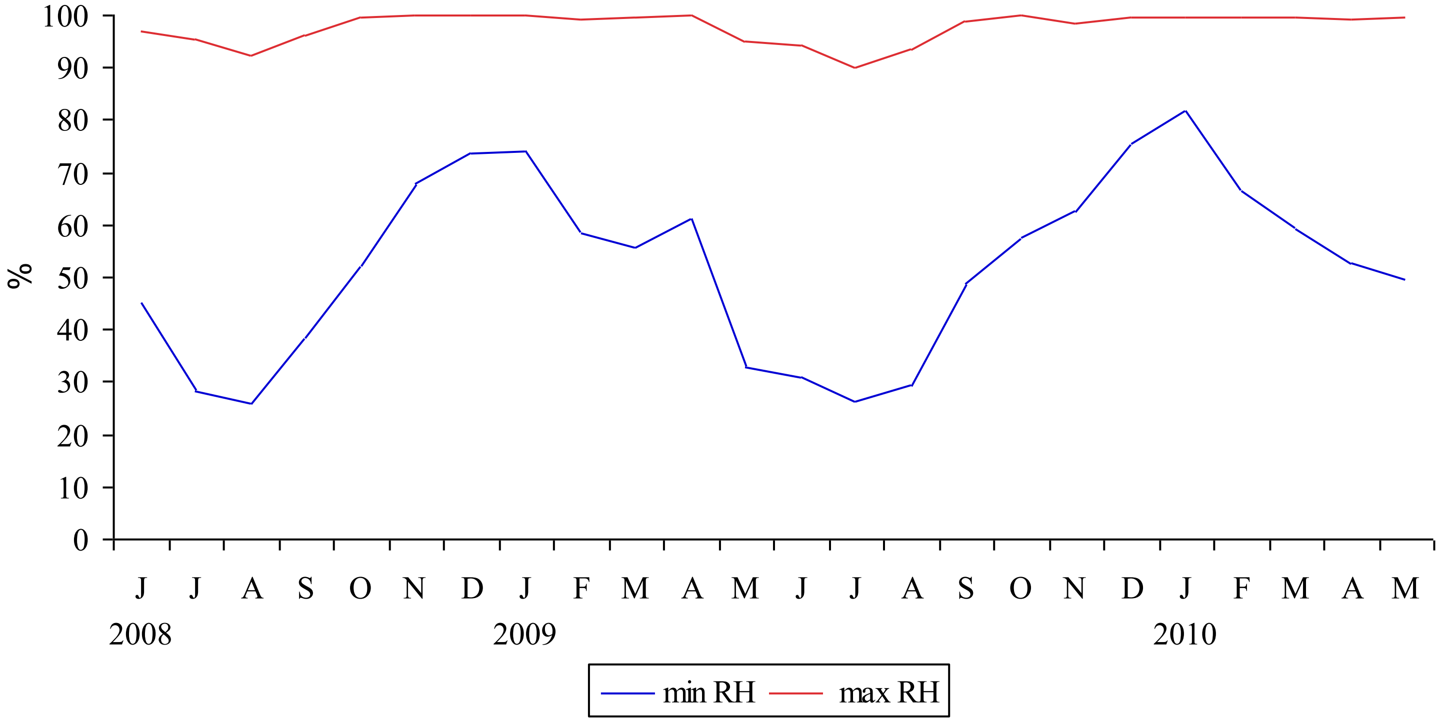

Figure 5 Range of the relative humidity from June 2008 to May 2010 at the Berchidda meteorological station (ARPA data).

3.2 Pedological characteristics of the study area

The study area was mainly represented by the hilly foothills of Mount Limbara; geologically, these consist of leucogranites and granodiorites of the upper Carboniferous–Permian, for the Berchidda and Monti areas, respectively (Geological Map of Sardinia, 1:200.000; Barca et al., 2001). The landscape is characterised by irregular versants of low to moderate slope. The pedological analysis focused on the pastures with the three grassland management types.

The main soils in area A are *Typic Dystroxerepts*, which are morphologically stable, and in which the pedogenic processes are more developed. The typical profile of these soils is given by the ABwC sequence, with thicknesses that reached, and in some cases exceeded, 100 cm, and a degree of base saturation below 35%. Where the bedrock was particularly shallow, like for the Lithic (<50 cm), but under the same physiographic conditions, the soils are of the *Dystric Xerorthents* type, which is characterised by poor development of the profile, although with an evident desaturation process, which is typical of soils formed on parent material rich in quartz, such as granites and their decay products. Finally where the soil thickness is reduced due to the physiographic position (with pronounced slope), there is the *Lithic Xerorthents* type.

The soils in area B mostly belong to *Typic Dystroxerepts*, with the base saturation below 60% for all of the horizons and depths between 25 cm and 75 cm from the mineral soil surface. In one case only, the stability conditions (slopes between 2% and 5%) and the resulting illuviation clay processes rose to Ultic Haploxeralfs soils, characterised by the ABtC sequence and by a low degree of base saturation.

In area C, *Lithic Xerorthents*, *Typic Haploxerepts* and *Typic Dystroxerepts* soil were found, in agreement with the pedological homogeneity that characterises the entire studied area.

The chemical fertility parameters showed homogeneity and were not significantly influenced by the three types of grassland management (Table 1). In heir A horizon, these acid sandy loam soils have a good content of organic matter, total nitrogen, assimilable phosphorus and exchangeable potassium, and a low content of calcium and available moisture. The impact of the agro-pastoral activities of mostly fertilisation and grazing organic residual might be responsible for the high average content of macroelements of some of these natural poor soils. Table 2 gives these fertility parameters for these three farm typologies. The soils of farm DC showed very high values, especially for the content of organic matter, assimilable phosphorus and exchangeable potassium, whereas the calcium was higher when compared to the average content of granite soil. These values were derived from the intensive management of farm DC, which included a large supply of animal manure and litter.

Finally, the pedological analyses did not note any significant differentiation for the soil characters between the three types of grassland management, A, B and C. The homogeneous geological substrates, such as the pedological processes, are spatially repeated each time under the same landscape conditions. This appears to be confirmed by the spatial variability of some of the characterisics, such as texture, pH, organic matter and bulk density. In contrast, the grazing system and animal typology can change the natural chemical fertility of soils as a function of the intensity of the farming system.

Table 1. Soil characteristics of the A horizon for the three types of grassland management. The data are means ± s.e.

Soil characteristic	Grassland management		
	A	**B**	**C**
Texture	Sandy loam	Sandy loam	Sandy loam
Thickness (cm)	34.0 ±6.2	30.0 ±3.5	27.5 ±3.2
pH	5.4 ±0.2	5.3 ±0.1	5.5 ±0.3
Organic matter (g kg^{-1})	29.5 ±10.8	24.1 ±2.3	28.1 ±3.3
Total nitrogen (g kg^{-1})	1.8 ±0.6	1.3 ±0.1	1.8 ±0.2
Assim. phosphorus (ppm)	15.4 ±10.0	9.6 ±2.3	25.9 ±16.0
Exchan. potassium (ppm)	268.8 ±108.5	116.8 ±20.3	106.5 ±5.3
Ca (ppm)	594.4 ±184.4	481.4 ±87.6	775.4 ±247.0
CEC[1] (me100g^{-1})	16.2 ±2.0	15.1 ±1.2	16.5 ±0.9
Bulk density (g cm^{-3})	1.5 ±0.1	1.6 ±0.0	1.5 ±0.0
Available moisture (%)	10.3 ±0.3	11.2 ±0.7	11.6 ±1.3

CEC=Cation Excange Capacity

Table 2. Soil characteristics of the A horizon for the three types of farm typology. The data are means ± s.e.

Soil characteristic	Farm typology		
	BC	**DC**	**DS**
Texture	Sandy loam	Sandy loam	Sandy loam
Thickness (cm)	30.0 ±4.6	21.7 ±6.0	35.0 ±3.1
pH	5.3 ±0.2	5.9 ±0.2	5.3 ±0.1
Organic Matter (g kg^{-1})	18.3 ±2.1	44.2 ±14.8	25.0 ±1.2
Total Nitrogen (g kg^{-1})	1.1 ±0.1	2.6 ±0.8	1.5 ±0.1
Assim. Phosphorus (ppm)	7.8 ±3.7	43.7 ±20.0	9.5 ±2.9
Exchan. Potassium (ppm)	107.3 ±46.7	313.7 ±184.4	146.2 ±14.9
Ca (ppm)	466.5 ±120.4	1085.7 ±297.3	479.6 ±64.5
CEC[1] (me100g^{-1})	13.6 ±1.5	17.9 ±2.7	16.3 ±0.5
Bulk density (g cm^{-3})	1.6 ±0.0	1.5 ±0.1	1.5 ±0.0
Available moisture (%)	10.0 ±0.5	11.0 ±0.9	10.0 ±1.7

CEC=Cation Excange Capacity

3.3 The farming system

3.3.1 Farm structure

The six farms studied had three family workers and one salaried worker at most (Table 3). The farm sizes ranged between 45 ha and 100 ha, and had a used agricultural area (UAA) always >44 ha. The percentage of UAA of the pasture land (non-cultivated land) was more than 58%. Although all of the farms had low intensity management, there were some relevant differences in the values of the cultivated land: the farms with the highest stocking rates, Sh 3 and Ca 1, had the highest cultivated surfaces (36% and 42% of UAA, respectively), whereas Ca 2 cultivated only 2% of the UAA. The crop system was annual cereal and forage species that were grown under rain-fed conditions. Oat (*Avena sativa* L), Italian ryegrass (*Lolium multiflorum* Lam.) and Balansa clover (*Trifolium michelianum* Savi syn *balansae*) were the most cultivated species, in rotation, with fallow also used in long-term crop sequences. The number of bred heads was very different between the farms, with an average of 293 in dairy sheep farms and 38 in beef cattle farms. The dairy cattle farm had 136 bred heads. The farm stocking rate, which was measured as livestock units per hectare (LU ha^{-1}), was always below 1.0 LU ha^{-1}, except for the dairy cattle farm (1.58 LU ha^{-1}). All of the dairy farms had a milk machine, with 12 or 24 places.

Table 4 shows the animal production and energy contributions of the different feed energy sources for the herd TER in 2009. The average milk production per hectare was 663 kg y^{-1} for the sheep farms, and 8914 kg y^{-1} for the cattle farm. Meat production was at a maximum of 114 kg $ha^{-1}y^{-1}$ for the Ca 3 beef farm. The feed supplements supplied from 6% (Ca 2) to 78% (Ca 1) of the animal TER. For the dairy sheep farms, the herbage from grazing covered more then 69% of the animal TER. For the most intensive system, the dairy cattle farm, the use of concentrates reached almost half of the high-energy requirements of the herd, whereas for the beef cattle farm, these did not cover more than 1%.

According to income from production sold *versus* feed costs, the economic balance of the farms is given in Table 5. These data were collected during interviews with the farm owners and they are related to market prices in 2009. The amount of milk sold was 40.5 t y^{-1} as the average for the sheep farms, and 641.8 t y^{-1} for the Ca

1 farm, which had the highest total income. The Ca 3 farm had the highest quantity of meat sold. Every farm purchased the wholeness of concentrate. Beef Ca 2 and 3 farms and Sh 1 farm produced their own hay and only one farm, Sh 3, did not produced any hay, as they used forage crops for grazing only. Sh 2 and 3 farms and Ca 1 farm purchased hay. The cost to produce crop forage was related to the land area cultivated, with the maximum and minimum values seen for Ca 1 and 2 farms, respectively. The difference between milk and meat income and feed costs (included cultivation cost) is an indicator of remunerative level of the farm labour. The highest value, €177,241 per year, was calculated for the dairy cattle farm, the most intensive system. In the sheep farms, farm 2 had the highest difference. This result derives from the good gain from the meat sold and the lower use of concentrate, when compared to Sh 3 and 1 farms. This last farm, Sh 1, also derived a lower income from low milk production.

Finally, very low net income characterised the two beef cattle farms, in which the farmers had gross deriving from others sources.

Table 3. The main structural traits of the six farms analysed.

Farm	Livestock species	Family workers	Salaried workers	Farm size	UAA	Pasture Land/UAA	CL/UAA	Forage crops	Flock/herd size	Stocking rate
		n.	n.	ha	ha	%	%		n.	LU ha^{-1}
Sheep 1	Dairy Sheep	3	0	61	53	81	19	Italian ryegrass, Oat Balansa clover	270	0.64
Sheep 2	Dairy Sheep	2	0	100	90	92	8	Italian ryegrass Subclover, Balansa. clover	315	0.46
Sheep 3	Dairy Sheep	0	1	52	50	64	36	Italian ryegrass, Oat, Barley, Crimson clover	295	0.81
Cattle 1	Dairy Cattle	3	0	80	72	58	42	Italian ryegrass, Oat, Winter wetch	136	1.58
Cattle 2	Beef Cattle	0	0.5	51	45	98	2	Italian ryegrass, Oat, Subclover	35	0.62
Cattle 3	Beef Cattle	1	0	45	44	77	23	Italian ryegrass, Oat Common wetch	40	0.70

UAA= Utilised Agricultural Area; CL= Cultivated Land; LU=Livestock units

Table 4. Milk and meat production and energy contributions of the different feed energy sources to herd TER in 2009.

Farm	**Livestock species**	**Milked animals**	**Milk production**	**Meat production**	**TER**	**Concentrate**	**Hay**	**Herbage**	**Total supplements**
		n.	kg $ha^{-1}y^{-1}$	kg $ha^{-1}y^{-1}$	UFL $ha^{-1}y^{-1}$	UFL $ha^{-1}y^{-1}$	UFL $ha^{-1}y^{-1}$	UFL $ha^{-1}y^{-1}$	%
Sheep 1	Dairy Sheep	200	588	38	1551	273	99	1180	24
Sheep 2	Dairy Sheep	250	500	44	1080	136	71	873	19
Sheep 3	Dairy Sheep	250	904	46	1882	409	166	1307	31
Cattle 1	Dairy Cattle	65	8914	19	6755	3004	2281	1470	78
Cattle 2	Beef Cattle	-	-	100	1306	6	74	1226	6
Cattle 3	Beef Cattle	-	-	114	1644	18	272	1354	18

Table 5. Milk and meat income and feed costs for the livestock farms in 2009

Farm	Milk sold	Meat sold	Milk price	Meat price	Milk income	Meat income	Purchased Concentrate.	Purchased Hay	Concentrate. cost	Hay cost	Crop cost	Difference Total income vs feed cost
	$t\ y^{-1}$	$t\ y^{-1}$	€ kg^{-1}	€ kg^{-1}	€ y^{-1}	€ y^{-1}	$t\ y^{-1}$	$t\ y^{-1}$	€ y^{-1}	€ y^{-1}	€ y^{-1}	€ y^{-1}
Sheep 1	31.1	2.0	0.7	3.0	21,806	6,500	15.8	0.0	4,255	0	2,340	21,171
Sheep 2	45.0	4.0	0.7	3.0	31,500	12,000	9.5	6.0	2,576	1440	1,687	37,798
Sheep 3	45.2	2.3	0.7	3.0	31,648	6,900	24.4	17.5	6,586	2271	3,014	26,677
Cattle 1	641.8	1.4	0.4	2.2	256,720	3,080	276.5	160.2	41,481	32033	9,045	177,241
Cattle 2	-	4.5	-	2.2	-	9,900	2.0	0.0	600	0	369	8,931
Cattle 3	-	5.0	-	2.2	-	11,000	3.0	0.0	900	0	2,485	7,615

3.3.2 Pasture characteristics

The highest grass H_m production of the pastures studied was always below 1.0 t ha^{-1}, and this was reached in May of both years (Table 6). The DC system showed higher forage production than the other grazing systems, particularly when compared to the BC farms that, on average, always had the lowest production. This can be explained by the high mineral fertility of the soils of the dairy cattle farm, due to large use of manure (see 3.3.3.1.). In the first spring, type C grazing management had a significantly higher H_m when compared to types A and B. This can be attributed to the residual effects of the recent agronomic practice of the preceding forage crop sown in the type C grasslands, such as mineral fertilisation or persistence of sown productive species (such as Italian ryegrass and Balansa clover). The average monthly growth rates of the pasture grass (Fig. 6) was very low and did not go over 15 kg $ha^{-1}d^{-1}$ in April of the second year. These values confirm the low productivity of these oligothrophic pastures, when compared with other hilly Sardinian pastures (Salis and Vargiu, 2005; Caredda et al., 1991; Spanu et al., 1998) and with '*dehesa* pastures' in the southwest of the Iberian peninsula (Olea and Viguera, 1997). This might arise from the characteristics of the soil, with especially low pH and available moisture, which will limit the growth capacity of the pasture plants.

A significant correlation was found between the grass height and pasture production (kg DM ha^{-1}) in the grazed and non-grazed pastures, in the autumn, winter and spring seasons (Table 7). In particular, the grazed pasture in autumn and the non-grazed pasture in winter had high and significant coefficients of determination. These two models allowed a good estimate of the pasture production, by measuring the canopy height with the weighted disc method.

Table 6. Seasonal average and maximun Hm (t ha^{-1} of DM) in the studied areas.

	Spring 2009			**Autumn -Winter - Spring 2009-10**		
GS	**Average**	**Maximum**	**Date**	**Average**	**Maximum**	**Date**
DS	0.4b	0.6b	25 may	0.3b	0.6ab	24 may
DC	0.5a	0.8a	4 may	0.4a	0.7a	3 may
BC	0.3c	0.5b	4 may	0.2c	0.5b	3 may
P	0.01	0.01		0.01	0.02	
GM						
A	0.4	0.6b	4 may	0.3	0.6	3 may
B	0.3	0.6b	25 may	0.3	0.5	24 may
C	0.5	0.8a	25 may	0.3	0.7	24 may
P	n.s.	0.01		n.s	n.s.	
GSxGM	n.s.	0.01		n.s.	n.s.	

GS=grazing system; GM=grassland management DS= Dairy sheep; DC= Dairy cattle; BC=Beef cattle.
Means with the same letters are not different.

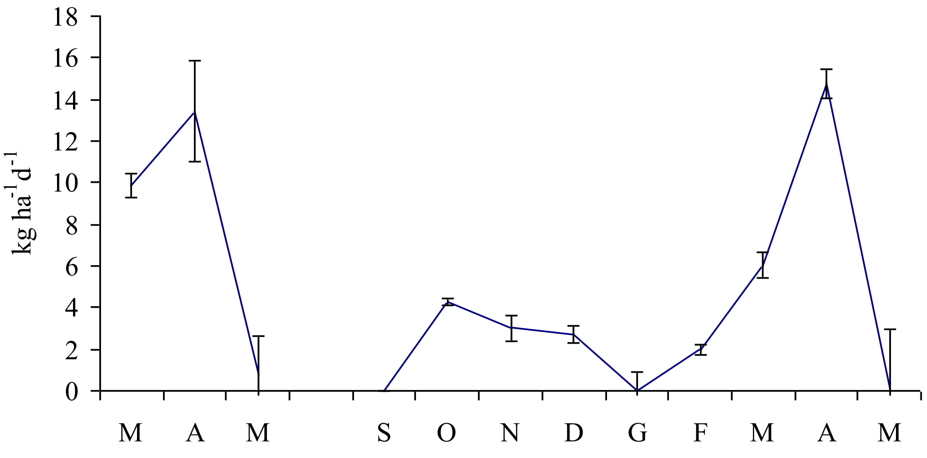

Figure 6. Average monthly growth rates (kg ha^{-1} d^{-1}) of the pastures, from March 2009 to May 2010. Vertical nar represent standard error

Table 7. Regression equations between the canopy height (x, cm) and the pasture production (y, kg DM ha^{-1}).

Season	Grassland management	Regression curve	R^2	P	x range
Autumn	grazed	y = 26.1x +3.1	0.82	<0.001	1-19
Winter	grazed	y = 33.2x -27.7	0.65	<0.001	0-11
Spring	grazed	y = 24.5x +46.7	0.71	<0.001	1-34
Autumn	non-grazed	y = 22.8x +57.5	0.44	<0.001	1-17
Winter	non-grazed	y = 38.7x -34.6	0.85	<0.001	1-17
Spring	non-grazed	y = 17.2x +65.5.	0.55	<0.001	2-62

The botanical composition data (Fig. 7) shows a good balance between legumes and grasses, which represented more than 60% of the total forage production in spring, and 40% in autumn. In particular, legumes represented more than 15% and 20% of the total DM of the pastures in autumn and spring, respectively. These values are higher than the average annual levels of legumes in '*dehesa*' pastures in the south-west of Iberia (Olea and Viguera, 1997). The presence of composite was higher in autumn, when with the groups of the other families represented 57% of the DM of the pastures. The proportion of botanical families was not significantly influenced by the different types of grassland management. In the grazing system types, in autumn and spring, farm BC showed a significantly higher level of legumes and a lower level of grasses than farm DC (Fig. 8; Fig. 9). In the two seasons, the DS farms had higher levels of grasses than legumes. The grazing system types did not affect the balance of the composites and the other families.

The chemical composition trend of the H_m in spring 2009 (Fig. 10) showed a good level of CP, which was roughly 20% of the DM until early April. At the end of May only, the level of CP decreased to under the level of 10%. In autumn and winter 2009-2010, the content of CP, NDF, ADF, and ADL were uniform enough. These values are similar to the other values in hilly pastures of central-western Sardinia (Sitzia and Fois, 2008).

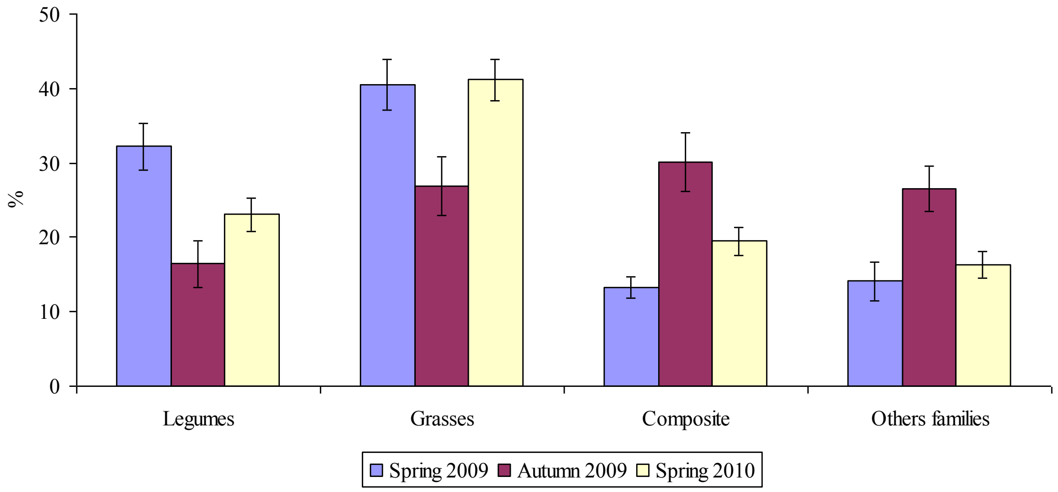

Figure 7. Botanical composition of pasture (% of total dry matter) in 2009 and 2010. Vertical nar represent standard error.

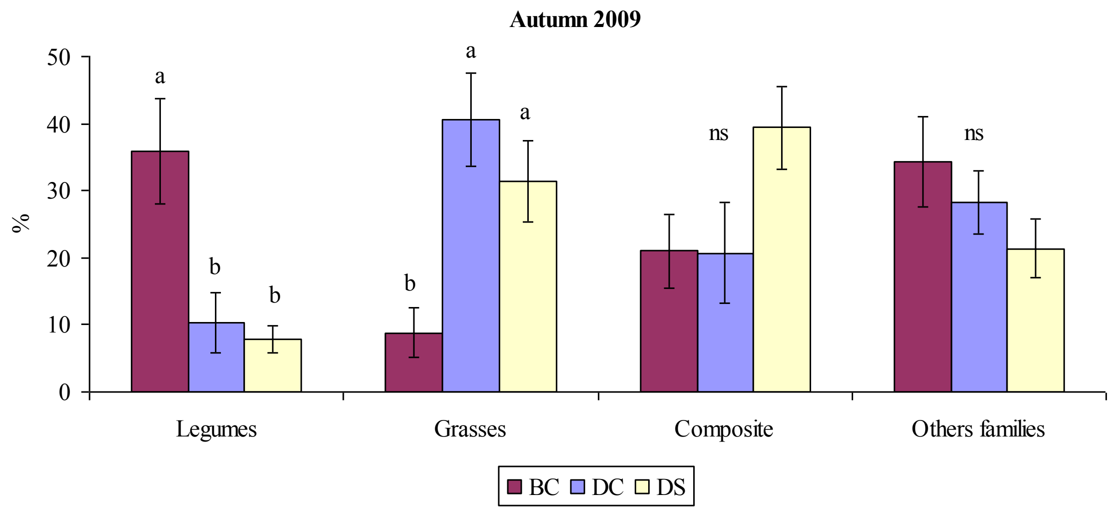

Figure 8. Botanical composition of pasture (% of total dry matter) of the different grazing systems in autumn 2009. Vertical nar represent standard error. Means with the same letters are not different at P≤0.05; ns= not significant.

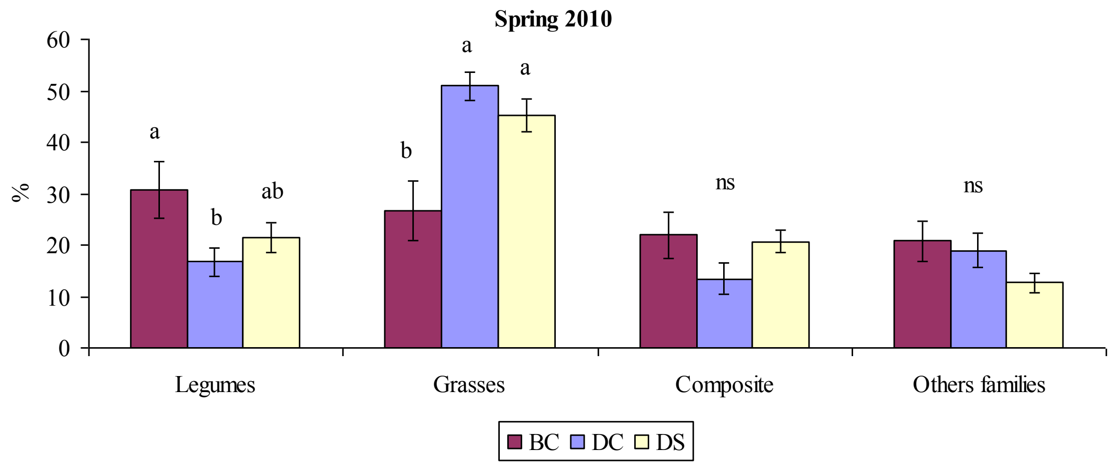

Figure 9. Botanical composition of pasture (% of total dry matter) of the different grazing systems in sprig 2010. Vertical nar represent standard error. Means with the same letters are not different at P≤0.05; ns= not significant.

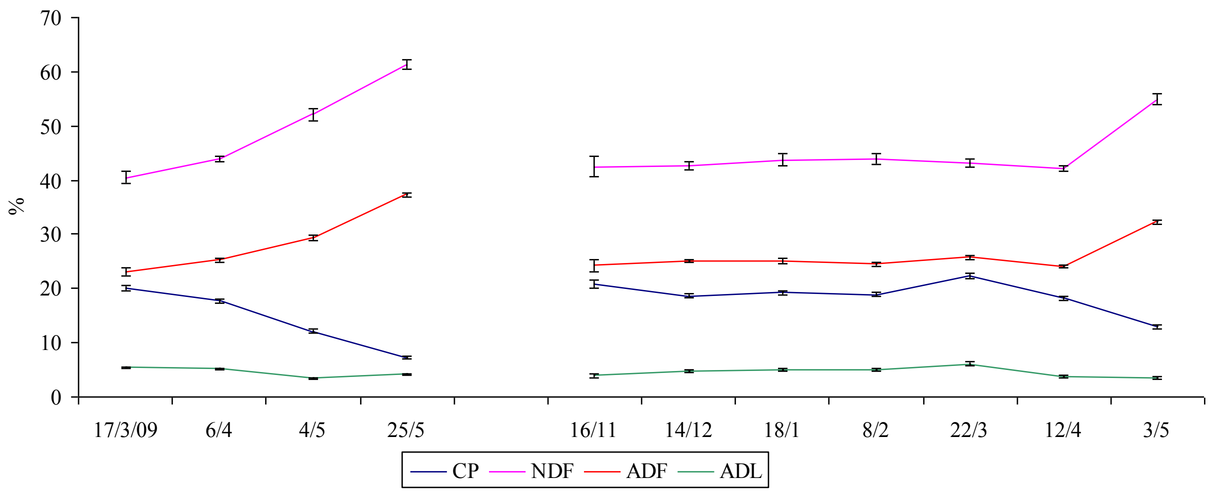

Figure 10. H_m chemical composition trend during the spring 2009 and from november 2009 to may 2010 in ungrazed pasture.Vertical nar represent standard error.

3.3.3 Grassland management

3.3.3.1 Agronomic techniques

All of the farmers adopted quite similar extensive agronomic management. Tillage mainly concerned superficial ploughing (20-30 cm in depth) and harrowing. Seeding was performed with a fertiliser spreader, with harrowing to cover the seed. Fertilisation was carried out using mineral fertiliser, to distribute roughly 40 kg ha^{-1} of N and P. For the dairy cattle farm, manure deriving from animal excrement was used, at 50 t ha^{-1}. The crops were grazed up to the end of winter, and than closed off from the animals to produce hay. For the Sh 2 farm only, forage crops were continuously grazed and they were not used to produce hay. Herbicides were not used, but in late spring or summer, most of the grassland was mowed for weed control, which were especially represented by thistle and asphodel.

3.3.4 Livestock management

3.3.4.1 Grazing management

For all of the farms, rotational grazing management was carried out, in each season. For the beef BC farms, the herd was moved to the highlands during the summer season. During the period of herbage sampling (spring and autumn 2009, winter and spring 2010), the stocking rate in the 14 field pastures of the six farms was very variable, with the highest values in a range from 2.1 LU $ha^{-1}d^{-1}$ in spring 2010 in type A fields of the beef cattle farms, to 7.9 LU $ha^{-1}d^{-1}$ in January 2010 in type A fields of the Sh 3 farm. For all of the fields, a few no grazing periods were carried out. The three types of grassland management, A, B and C, did not significantly differ in their SR, SER and O_i (Table 8). The pastures of the sheep farms showed significantly higher values of SR than the pastures of the cattle farms (1.9 and 0.9 LU $ha^{-1}d^{-1}$, respectively). This provided a higher O_i too (2.0 *vs*. 0.8). Figure 11 shows the trend of the H_o values during the period of herbage sampling, which confirms the stocking rate data. Generally, H_o was lower in the pastures grazed by sheep than in those grazed by cattle, except in the late spring of 2009. For the dairy and beef cattle farms, the pastures had the same levels of SR, although the former showed lower O_i than the latter, due to the high level of supplements given to the animals, which covered most of the TER (Fig. 12).

Table 8. Values of SR, SER and Oi in GS and GM types of the studied areas.

Pasture	**SR** (LU ha^{-1}d^{-1})	**SER** (UFL ha^{-1}d^{-1})	**O$_i$**
GS			
Sheep	1.9	13.1	2.0
Cattle	0.9	5.4	0.8
P	0.01	n.s.	0.03
GM			
A	1.8	11.5	1.9
B	1.1	7.4	1.2
C	1.2	8.8	1.1
P	n.s.	n.s.	n.s.
GSxGM	n.s.	n.s.	n.s.

GS=grazing system; GM=grassland management; n.s.= not significant

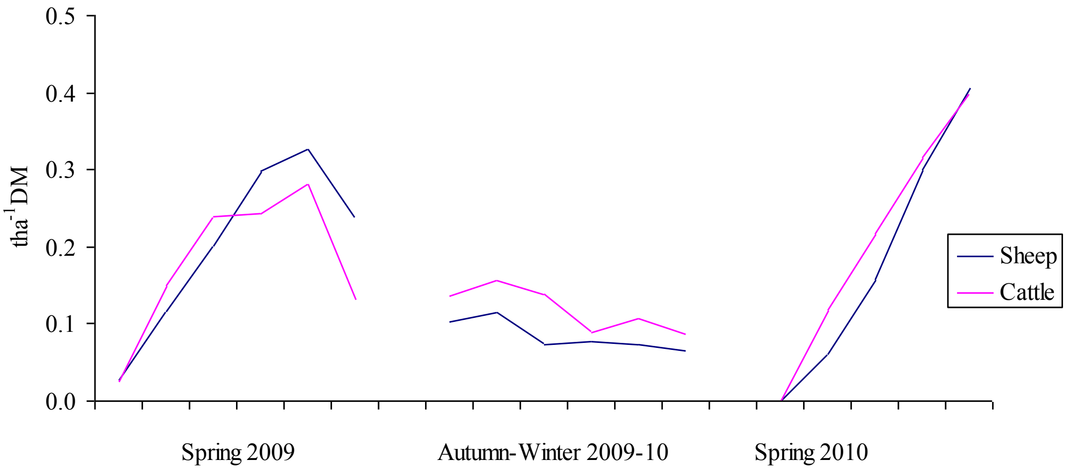

Figure 11. H$_o$ (Herbage on offer) for the sheep and cattle farms.

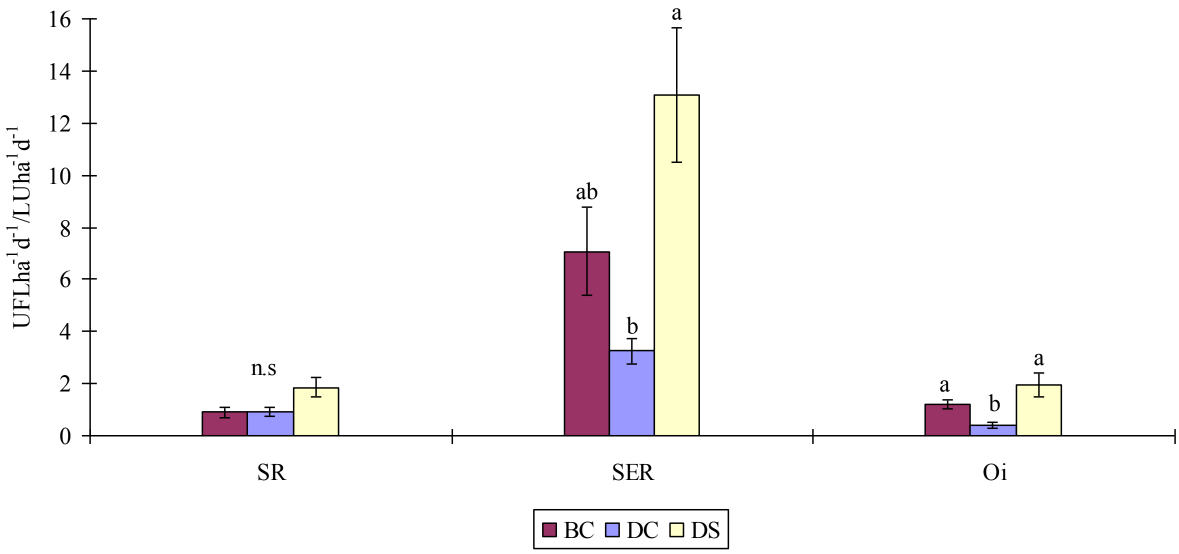

Figure 12. SR (Stocking rate, LU $ha^{-1}d^{-1}$), SER (Stocking rate energetic requirements, UFL $ha^{-1}d^{-1}$) and Oi (Overgrazing index) in the different grazing systems. BC=beef cattle; DC=dairy cattle; DS=dairy sheep. Vertical nar represent standard error. ns=not significant. Means with the same letters are not different at P=0.05.

3.3.4.2 Animal feeding

On the sheep and beef cattle farms, the natural and cultivated pastures were the main source of animal feed. For the dairy cattle farm only, the pasture provided <70% of TER (Fig. 13). In this intensive feeding system, the use of concentrate cover about 45% of the animal TER, as yearly average value. In particular, during the dry season, the energy that was derived from concentrate exceeded half of the TER, reaching 57% in June, as the maximum. During this period, he animals had taken in roughly 10 kg head^{-1}d^{-1} of maize meal and dehydrated maize pellets. High quality hay was offered to the herd (lucerne and Italian ryegrass, mainly), at roughly 2400 kg head^{-1}y^{-1}, which satisfied more than 30% of the TER. In summer, the animals derived only 7% of TER from herbage, and they never exceeded 30% during the year.

On the other hand, the beef cattle farm feeding system was based on the highest level of grazing pastures, that covered 82% of the TER, as the average over the year, and 100% in May and June. During the summer, the calves were supplemented with concentrate, and a small amount of hay was supplied to the herd.

For the dairy sheep farm animals, the TER were covered to 73% by herbage, with the highest values in spring, and always above 80% (Fig. 14). Concentrate was supplied in various quantities from 42 kg head^{-1}y^{-1} for Sh 2 farm to 109 kg head^{-1}y^{-1} for Sh 3 farm, and it covered 17% of the TER as the average over the year. The value of 109 kg head^{-1}y^{-1} for Sh 3 farm is similar to the average quantity supplied in the Sardinia farming system (Natale et al., 2002; Idda et al., 2010). The hay was given overall in autumn, during the dry period for the sheep, which covered up to 32% of the TER. The total amount supplied ranged from 54 kg head^{-1}y^{-1} for Sh 2 farm, to 122 kg head^{-1}y^{-1} for Sh 1 farm. Also, during the milking period, the level of concentrate supplied was the lowest for Sh 2 farm, which integrated the animals with hay (Tab. 9). On this farm, the sheep spent a greater time on heir grazing due to the greater land availability, which corresponded to the lowest stocking rate. Sh 2 farm also achieved the highest milk yield (0.93 l head^{-1}d^{-1}), when compared with Sh 1 and 3 farms (0.66 and 0.83 l head^{-1}d^{-1}, respectively), which represented a higher value with respect to the average values of the dairy sheep farming system in Sardinia (Idda et al., 2010).

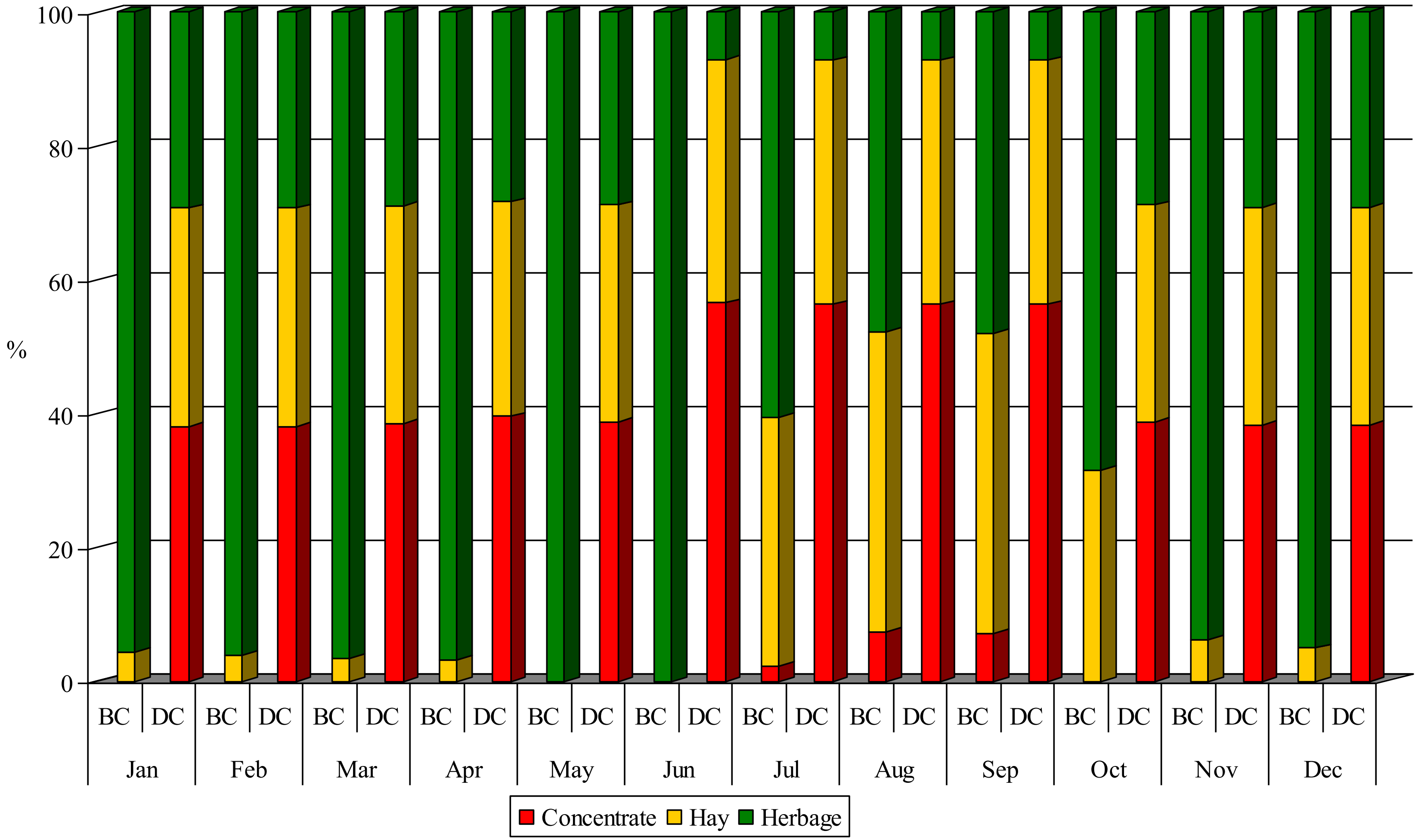

Figure 13. Relative energy intake (%) from the concentrate, hay and herbage for the beef cattle (BC) and dairy cattle(DC) farms.

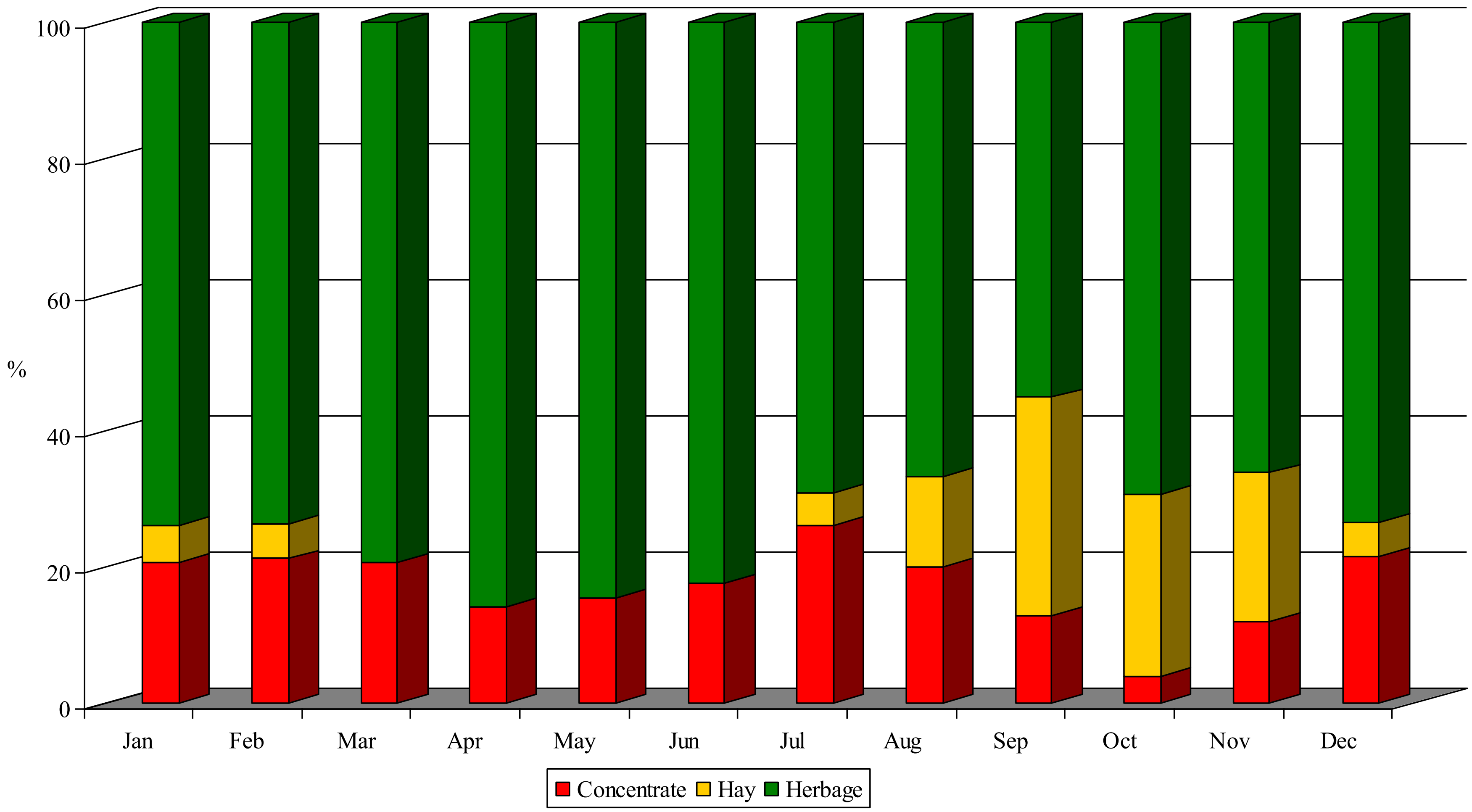

Figure14. Relative energy intake (%) from concentrate, hay and herbage for the dairy sheep farms

Table 9. Concentrate and hay ingested during the milking period and milk production for the three sheep farms.

Farm	**Concentrate** (g head^{-1}d^{-1})	**Hay** (g head^{-1}d^{-1})	**Milk production** (l head^{-1}d^{-1})
Sh 1	236	0	0.66
Sh 2	202	171	0.93
Sh 3	392	0	0.83
Average	277	6	0.81
±s.e.	±5.9	±5.7	±0.08

4 Conclusions

The livestock farms studied here are not only representative of Gallura, but also of the most widespread regional farming systems. As family businesses, of a small size and with high grazing of the natural pasture were the main characteristic traits of these farms. The environmental conditions, as mainly defined by the meteorological and soil characteristics, indicated vegetation patterns of '*dehesa* landscapes' for these different types of farm systems. The homogenous pedological conditions were not decisive for the choice of farm management, which appears to have been more influenced by the organisational factors and the land availability Only in a few areas were there marked natural characteristics, such as the presence of rock outcrops or high density cork, that might have had influence on the choice of agronomic practices and grazing management.

The intensity of the farm management depends on the bred of the animal species and the farm size. Generally, the livestock management is based on the maximum use of natural pasture, with integration of an animal diet with supplements, depending on the physiological stage and the season. For the dairy cattle farm, where the intensive system requires high constant energy levels, supplements are provided mostly in summer, to substitute for the lack of pasture resources; however, for the rest of the year the supplements covered roughly 70% of the animal TER. Herd management was affected by the high energy requirements of the animals that spent less time in grazing (5-7 hours each day) and spent more time in an open paddock, with the intake of hay and feedstuff. Consequently, the natural pastures were subjected to low stocking rates and to undergrazing. On the other hand, the intensive farm system also provided a large amount of manure, which was spread on the natural pasture, and which changed the fertility of the oil, increasing its organic matter and macroelement content and affecting the balance between the main botanical families. From the other side, the beef cattle farms showed extensive management with very low supplements supplied, and mainly as hay, the animals remaining at pasture throughout the year, with a medium level of grazing pressure. This farm system is seen to be the most natural and environmentally friendly between the farming systems studied, due to the rational use of the pastures and the livestock management adopted. In the economic balance between production income and feed costs, the DC and BC systems are very different, as they have the highest and lowest net incomes, respectively. The low economic sustainability of the BC system justifies the presence of others business activity of the owners of the farms.

The dairy sheep farms analysed represent the most widespread farm system in Sardinia. The low agronomic input (low level of mineral fertiliser, shallow tillage, and no herbicide), which also answered to economic reasons, increases the environmental sustainability of these farm systems. The high grazing pressure of the natural pastures studied, in contrast to the low farm stocking rate, can be explained because these pastures were often used for animal permanence after grazing on highly productive forage crops, where their nutrient requirements were partially satisfied. Nevertheless, these dairy sheep grazing systems, have high instant stocking rates, and marked pastures that have, on average, lower forage residuals after grazing than the pastures grazed by the cattle. In this context, with non-productive pastures, the farm size has an important role in the feed management and the economic balance. The farm with the highest level of land available and the maximum use of grazing needed the lowest quantity of supplements, and had the highest net income. Moreover, the highest milk production per head confirms the efficiency of the system. I can also be noted that in the sheep farms, the most extensive management is also the most economically sustainable system.

Differences were seen between the farm systems that indicate the presence of various patterns of agronomic and grazing management in the *dehesa* agro-pastoral system that can influence some of the natural environmental characteristics. Studies of how the management and environmental factors can affect vegetation factors and grazing values of pastures represent important issues in our understanding of the roles of the variation and maintenance of the natural level of biodiversity in the grazed pasture of the farming systems studied here.

References

Arrigoni P.V. (2006). Flora dell'Isola di Sardegna. Carlo Delfino editore.

Bacchetta G., Bagella S., Biondi E., Farris E., Filigheddu R., Mossa L. (2009). Vegetazione forestale e serie di vegetazione della Sardegna (con rappresentazione cartografica alla scala 1:350.000). Fitosociologia, 46, 3-82.

Blasi C., Carranza M.L., Frondoni R., Rosati L. (2000). Ecosystem classification and mapping: a proposal for Italian landscapes. Applied Vegetation Science, 3, 233-242.

Caballero R., Fernàndez-Gonzàlez F., Perez Badia R., Molle G., Roggero P.P., Bagella S., D'Ottavio P., Papanastasis VA., Fotiadis G., Sidiropoulou A., Ispikoudis I. (2009). Grazing systems and biodiversity in Mediterranean areas: Spain, Italy and Greece. Pastos, 39,1, 9-53.

Caredda S., Porqueddu C., Roggero P.P., Sanna A., Casu S. (1991). Feed resources and feed requirements in the sheep agro-pastoral system of Sardinia. IV° Congrés International des Terres de Parcours, Montpellier, France.

Coelho I.S. (1992). Valores econòmicos e ambientais do montado. Temas de Econonomia e Sociologia Agràrias. Istituto Nacional de Investigaçao Agraria Lisboa, 17-43.

Gaspar P., Escribano M., Mesìas F.J., Rodriguez de ledesma A., Pulido F. (2008). Sheep farms in the Spanish rangelands (dehesas): Typologies according to livestock management and economic indicators. Small Ruminant Research 74, 52-63.

Gaspar P., Mesìas F.J., Escribano M., Rodriguez de Ledesma A., Pulido F. (2007). Economic and management characterization of dehesa farms: implications for their sustainability. Agroforest syst. 71:151-172.

Idda L., Furesi R., Pulina P. (2010). L'allevamento ovino in Sardegna. In Economia dell'allevamento ovino da latte. Franco Angeli, Milano, Italia, 53-97.

Joffre R., Vacher J., De Los LLanos C., Long G. (1988). The dehesa: an agrosilvopastoral system of the Mediterranean region, with special reference to the Sierra Morena area of Spain. Agroforestry Systems 6, 71-96.

Joffre R., Hubert B., Meuret M. (1991). Les systemès agro-sylvo-pastoraux mediterranèens: enjeux et reflexions pour une gestion raisonnèe. Dossier MAB 10, UNESCO, Paris, France, 1-96.

Loi A., Cocks P.S., Howieson J.G., Carr S.J. (1999). Hardseededness and the pattern of softening in *Bisserula pelecinus* L. *Ornithopus compressus* L., and *Trifolium subterraneum* L. seeds. Australian Journal of Agricultural Research, 50, 1073-1081.

Natale M.A., Oppia P., Contu M., Ligios S., N. Fois. (2002). Description des mutations structurelles, démographiques et economiques dans un échantillon ovines laitiéres de 1996 à 2000 en Sardaigne. Options méditerranéennes. Serie A: Séminaires Méditerranées. Alghero, Italie, 61, 67-71.

Olea L., Viguera F.J. (1997). Dehesa ecosystem: production and preservation. 9° Meeting of the Mediterranean Sub-Network of the FAO-CIHEAM. Inter-Regional Cooperative Research and Development Network on Pastures and Fodder Crops, 239-246.

Pagliai M. (eds.), (2001). Metodi di analisi fisica del suolo. Collana di metodi analitici per l'agricoltura. Edizione Franco Angeli.

Roggero P.P., Bellon S., Rosales M., (1996). Sustainable feeding systems based on the use of local resources. Annales de Zootechnie 45, 105-118.

Rossi G., Tellarini V., Pulina G., Campus F., Brindano P., Lucifero M. (1985). Contributo alla razionalizzazione dell'allevamento estensivo: organizzazione e dimensionamento del carico di aziende indirizzate verso la produzione di vitelli da ristallo. Zootecnia e nutrizione animale, Anno XI supplemento al n.5 .

Salis L., Vargiu M., Spanu E., Loche F. (2005). Overgrazing influence on the presence of legumes in a natural pasture of Sardinia. "XX International Grassland Congress: Offred papers", 635.

Sitzia M., Fois N. (2008). Dairy sheep system based on natural pasture in a Sardinian hill: milk production and feedstuff supplementation. Proceedings of 22th EGF Biodiversity and Animal Feed: future challenges for grassland production. Eds. A. Hopkins, T. Gustafsson, J. Bertilsson, G. Dalin, N. Nilsdotter-Linde, E. Sporndly, 858-860.

Shenk J.S., Westerhaus M.O. (1994). Population definition, sample selection and calibration procedures for near infrared reflectance spectroscopy. Crop Science, 31, 19-27.

Spanu E., Ligios S., Vargiu M., Arangino R., Fois N., Molle G. (1998). Atti del Convegno S.I.A. "Sistemi colturali di collina: tradizione e innovazione per un'agricoltura sostenibile", Ancona.

Violante P. (eds.), (2000). Metodi di analisi chimica del suolo. Collana di metodi analitici per l'agricoltura. Edizione Franco Angeli.

C) Grazing systems and plant biodiversity in semi-natural grasslands of the *dehesa* landscape

Key words: abiotic factors, cattle, CCA, dairy sheep, grazing value, plant functional traits, Sardinia.

1 Introduction

The awareness of the importance of low intensity grazing systems for conservation of plant biodiversity and as a source for other service and benefits has grown in the recent decades (Peco et al., 2006; Koniak et al., 2009). Extensive and large scale grazing systems represent one of the best adapted land uses in marginal rural areas of the European Union (Caballero et al., 2009). An emblematic example of these systems is the *dehesa* which is a traditional Mediterranean silvopastoral system linking production and nature conservation, developed on poor or non-agricultural land and aimed at extensive livestock raising (Olea et al., 2006). It is an open woodland of *Quercus* sp. with an understorey of grasslands, cereal crops or Mediterranean scrub located on poor sandy acidic soils (Peco et al., 2005). The major goal of land cultivation is preventing the shrub invasion of grasslands and supplying fodder and grain for livestock, harvesting being a secondary goal (San Miguel, 1994, 2005; Montero et al., 2000). According to Olea et al. (2005), the typical dehesa is located in the South Western part of the Iberian Peninsula, in Spain and Portugal (where it is named *montado*), covering an area of about 3.5 – 4 million hectares. Systems such *dehesa* and *montado* of the Iberic Peninsula also exist in various other Mediterranean countries including Morocco, Algeria, Tunisia, Southern France (mainly Corsica), Italy (Sardinia), Greece (Joffre et al., 1988). In Sardinia they were recently indicated also as *meriagos* because in the Sardinian language *meriago* is a shady place were livestock take care from the sun (Puxeddu et al., 2008; Ramanzin et al., 2009). Like for the typical environment of the Spanish *dehesa* (Olea and San Miguel, 2006) *meriagos* present two fundamental features: the Mediterranean character of the climate (dry summers and somewhat cold winters) and the low fertility of the soil, making arable farming unsustainable and unprofitable. The tree layer is represented by *Quercus suber* scattered trees derived by the acidophilous, Mesomediterranean, subhumid cork-oak mesowoods ascribed to *Galio scabri-Quercetum suberis* association and by the neutroacidophylous mesomediterranean, subhumid-humid cork-oak mesowoods ascribed to *Violo dehnhardtii-Quercetum suberis* (Bacchetta et al., 2004). According to the Habitats Directive (EC, 1992) Sardinian *dehesa* was included in the habitat type 6310 - *Dehesas* with evergreen *Quercus* spp. (Petrella et al., 2005).

The most important objective of the *dehesa* is extensive livestock rearing. Therefore, seminatural pastures, as the main source of fodder for livestock, are an essential component of the system. As a consequence of the Mediterranean climate, they are usually annuals. However, perennials play a fundamental role in valley bottoms and particularly in dense swards created and maintained by intense and continuous grazing (Olea et al., 2006).

The management of grassland is aimed at increasing their quality since quantity is much less important due. The tillage, traditionally developed in periodical rotation cycles, is a frequently applied practice for the cultivation of cereals and legumes, as well as for the control of shrub advance (Montero et al., 1998). Changes in management towards estensification or intensification both in short or long-term results in the modification of vegetation richness, composition and structure (Sebastià et al., 2005; Peco et al., 2006; Královek et al., 2009; Farris et al., 2010) and in biomass production and nutritive value (Mariott. et al., 2004).

In this research we aimed to evaluate the possible effects of some relevant management variables, including grazing animals, grazing intensity and tillage treatment on plant biodiversity in seminatural grasslands of *dehesa* landscape in Sardinia and in case which should be the main factors affecting the variability. Firstly we analyzed the variability in plant assemblages under different treatments, secondly we compared the assemblage parameters of the assemblages and finally we checked for the relationships between plant assemblages and environmental and management variables.

2 Materials and methods

2.1 Location and sampling

The vegetational study was performed in the same area and farms of agronomic and structural characterization (see part B section 2). In order to minimize the effects of the abiotic factors on the vegetation, the sample sites were selected within the same "environmental unit" as defined by Blasi et al. (2000), in which the potential vegetation was represented by neutro-acidophylous cork-oak meso-woods of the association *Violo dehnhardtii-Quercetum suberis* (Bacchetta et al. 2009). In the six livestock farms (one with dairy cattle, Ca 1, two with beef cattle, Ca 2 and Ca 3, and three with dairy sheep, Sh 1, Sh 2 and Sh 3) we focused thirteen pastures characterized by three different types of grassland management (GM) A, B and C (see part B section 2). The sampled fields were chosen randomly in the area, taking into account of the availability of the farmers and the dominant livestock systems in the area.

Three 5x5 m fences were randomly positioned in each field. Vegetation surveys were carried out in each plot on May of the same year along two transects at 50 vertical point quadrates (Bullock 1996). Then the Specific Contribute of Presence (CSP) was assessed for each species (Daget & Poissonet, 1971). Moreover a census of plant species present in each fenced plot was carried out during the whole year in order to assess species richness.

Plants were classified following Pignatti (1982) and categorized into life forms (Raunkier 1934), functional groups (Noy Meyer et al., 1989; Stenberg et al., 2000; Aboling et al., 2008) and specific grazing value index (Roggero et al., 2002).

Functional groups were recognized according to life cycle, plant height at flowering, palatability and taxonomy the following: perennial tall (PTGR) and annual tall grasses (ATGS) >50 cm in height; annual short grasses (ASGR) <50 cm in height; annual legumes (ALEG); perennial (PTHI) and annual thistles (ATHI); annual crucifers (ACRU), grouped separately because their low palatability; annual forbs (AFOR), including all the dicots not considered in the previous groups; and geophytes (GEOP).

Each field was characterized by pedological point of view and stocking rate and grazing management were monitored (see part B section 2).

2.2 Data analysis

2.2.1 Variability in plant assemblages

Floristic, structural and functional features were considered for the evaluation of plant assemblage variability.

Species cover values for each field were calculated by averaging the data across the three fences. These values were used to construct the fields x species CSP floristic matrix, describing the floristic space. The similarities matrix between each sample pair was calculated using the Bray–Curtis similarity coefficient (Bray & Curtis 1957).

A cluster analysis was performed to produce a dendrogram of the samples based on the complete linkage algorithm, in order to identify homogeneous groups of samples. Formal significance test for differences between the groups was conducted by one-way analysis of similarities (ANOSIM) permutation/randomization tests (Clarke & Warwick 2001). If significant, the similarity percentage procedure (SIMPER) was employed to identify the major plant species contributing to the average dissimilarity among groups (Clarke 1993).

On the basis of the different aggregation criteria, two matrices were derived from the floristic matrix, describing respectively the structural and the functional space: a fields x life forms CSP matrix and a fields x functional traits CSP matrix. In order to verify the coherence of the floristic groups in the structural and functional space ANOSIM was calculated. When significant, the similarity percentage procedure (SIMPER) was employed to identify the major types (e.g. life forms and functional traits) contributing to the average dissimilarity among groups (Clarke 1993).

Cluster, ANOSIM and SIMPER analysis were carried out with PRIMER v6 (Clarke & Gorley 2006).

2.2.2 Assemblage parameters

Three assemblage parameters were calculated: species richness, diversity and grazing value. Species richness per plot was calculated as the total number of species collected throughout the studied period. Total species for field was calculated as cumulative value recorded in the three plots. Diversity was calculated using

Shannon-Wiener index with $\log_2$ (Pielou 1969). The grazing value was assigned to each field, following the phytopastoral method (Daget & Poissonet, 1971).
The analysis of variance (ANOVA) was used to test for differences between assemblage parameters of each the group identified throughout the cluster analysis. Prior to the analysis, the homogeneity of variance was tested with Cochrans' test (Winer 1971) and data were transformed whenever necessary.

2.2.3 Relationships between plant assemblages and explanatory variables

A Canonical correspondence analysis (CCA) was used to perform direct gradient analysis and identify environmental and management variables potentially influencing plant assemblages.
The floristic matrix, square-root-transformed and down-weighted for rare species (ter Braak & Šmilauer 2002), was considered as response variable and environmental and management variables as explanatory ones. All the environmental and management variables (Table 1), were included in the first step of the analyses. The most important variables were then identified by forward selection. Only statistically significant factors at $P<0.05$ confidence level were selected for the final analysis.
The numeric variables, except pH, were log-transformed using natural logarithms. Grazing animal species and tillage treatment were included in the analyses using a fuzzy coding and introduced as fuzzy variables. The statistical significance of Axes 1 and 2 was tested by using a Monte Carlo permutation test with 199 permutations under the full model. CCA, Monte Carlo test, and the forward selection were carried out with CANOCO 4.5 for Windows (Braak & Šmilauer 2002).

Table 1. Environmental and management variables recorded for each field and used for the CCA.

Farm	**Sh 1**	**Sh 1**	**Sh2**	**Sh2**	**Sh2**	**Sh 3**	**Ca 1**	**Ca 1**	**Ca 1**	**Ca 2**	**Ca 2**	**Ca 2**	**Ca 3**
GM	**B**	**C**	**A**	**B**	**C**	**B**	**A**	**B**	**C**	**A**	**B**	**C**	**A**
Field	**1**	**2**	**10**	**11**	**12**	**13**	**6**	**7**	**8**	**3**	**4**	**5**	**9**
Environmental variables													
Soil characteristics													
Thickn. A+B horizons (cm)	40	93	90	55	50	55	70	50	25	35	85	40	110
Sand (g kg^{-1})	656	736	604	606	553	822	588	677	663	872	668	553	717
Clay (g kg^{-1})	130	133	147	137	0	53	147	113	121	82	82	141	101
pH	5.2	5.0	5.2	5.2	5.22	5.7	6.0	5.6	6.2	5.3	4.9	5.6	5.1
SOC (g kg^{-1})	16.2	13.9	13.1	17.2	15.1	14.0	41.9	12.9	22.1	10.0	9.8	14.1	8.6
Assimilable P (ppm)	6.65	22.00	1.96	17.15	4.58	12.94	53.30	5.32	72.56	1.33	5.98	5.43	18.50
Bulk density (cm^{3-1})	1.53	1.26	1.56	1.51	1.45	1.55	1.26	1.68	1.48	1.62	1.64	1.51	1.52
Management variables													
GS													
Sheep	+	+	+	+	+	+							
Cattle							+	+	+	+	+	+	+
Oi	2.37	0.77	4.07	2.72	3.23	1.00	0.17	0.65	0.82	0.84	1.50	1.93	2.14
SR (UFL $ha^{-1}d^{-1}$)	7.7	5.2	17.0	14.4	13.9	6.7	1.7	3.2	2.1	2.3	3.3	5.9	6.7
GM													
A			+				+			+			+
B	+			+		+		+			+		
C		+			+				+			+	

Sh=Sheep; Ca= Cattle; GS= Grazing system; GM=Grassland management; Oi=Overgrazing index; SR=Sstocking rate

3 Results

3.1 Variability in plant assemblages

A total of 153 plant species were recorded inside the fenced plots. The most represented families were *Poaceae* (22%), *Asteraceae* (19%) and *Fabaceae* (15%). Annuals were more abundant (68%) than perennials, which were mainly represented by Hemicryptophytes (28% of the whole flora).

The hierarchical classification of the samples (Fig. 1) pointed out three groups (cut level=25%) based on floristic affinities. Differences between groups were globally significant (Global R=0.57; significance level of sample statistic = 0.001), the groups better separated being 2 and 3 (R=0.81; significance level of sample statistic = 0.001).

The floristic space was therefore characterized on the basis on the groups that were identified throughout the hierarchical classification. There were 15 species with CSP>5 in at least one of the groups and no species had a CSP > 12. *Trifolium subterraneum* was the most abundant species overall and in groups 1 and 2, while in group 3 the most abundant species was *Anthemis arvensis* (Fig. 2a).

Therophytes were strongly dominant in the three groups, followed by the Hemicriptophytes (Fig. 2b).

In term of functional groups, AFOR were the most represented, followed by ALEG and ASGR (Fig. 2c).

Group 1 included all the samples collected from sheep grazed fields, group 2 included all the samples carried out in cattle grazed fields except for Ca 2 type A and Ca 2 type B which were included in group 3. In the comparison between group 1 and 2, a total of 42 species accounted for the 90% of the dissimilarity with contributions between 8.0 and 0.6%. The major contributions to the dissimilarity (%>5) were given by: *Avena barbata*, *Vulpia ligustica*, *Trifolium subterraneum*, *Lolium rigidum*, *Medicago arabica*. In the comparison between group 1 and 3 a total of 40 species accounted for the 90% of the dissimilarity with contributions between 7.4 and 0.5%. The major contributions (%>5) were given by: *Vulpia ligustica*, *Trifolium subterraneum, Avena barbata*, *Plantago coronopus, Silene gallica, Anthemis arvensis*. In the comparison between group 2 and 3 a total of 23 species accounted for the 90% of the dissimilarity, with contributions between 9 and 0.6%. The major contributions (%>5) were given by: *Anthemis arvensis, Lolium rigidum, Plantago coronopus, Silene gallica, Avena barbata*, *Medicago arabica*.

The coherence of the floristic groups was not confirmed in the structural space (Global R=0.095; significance level of sample statistic = 0.04) because the strong dominance of Therophytes.

The coherence of the floristic groups was instead confirmed in the functional one (Global R=0.5; significance level of sample statistic = 0.001). In the comparison between group 1 and 2 the major contributions to the diversity was given by: AFOR (contribution to the dissimilarity, 17%), ATGR (16%) and ASGR (16%); in the comparison between group 1 and 3 by: AFOR (35%) and ALEG (15%); in the comparison between group 2 and 3 by: AFOR (39%) and ATGR (17%).

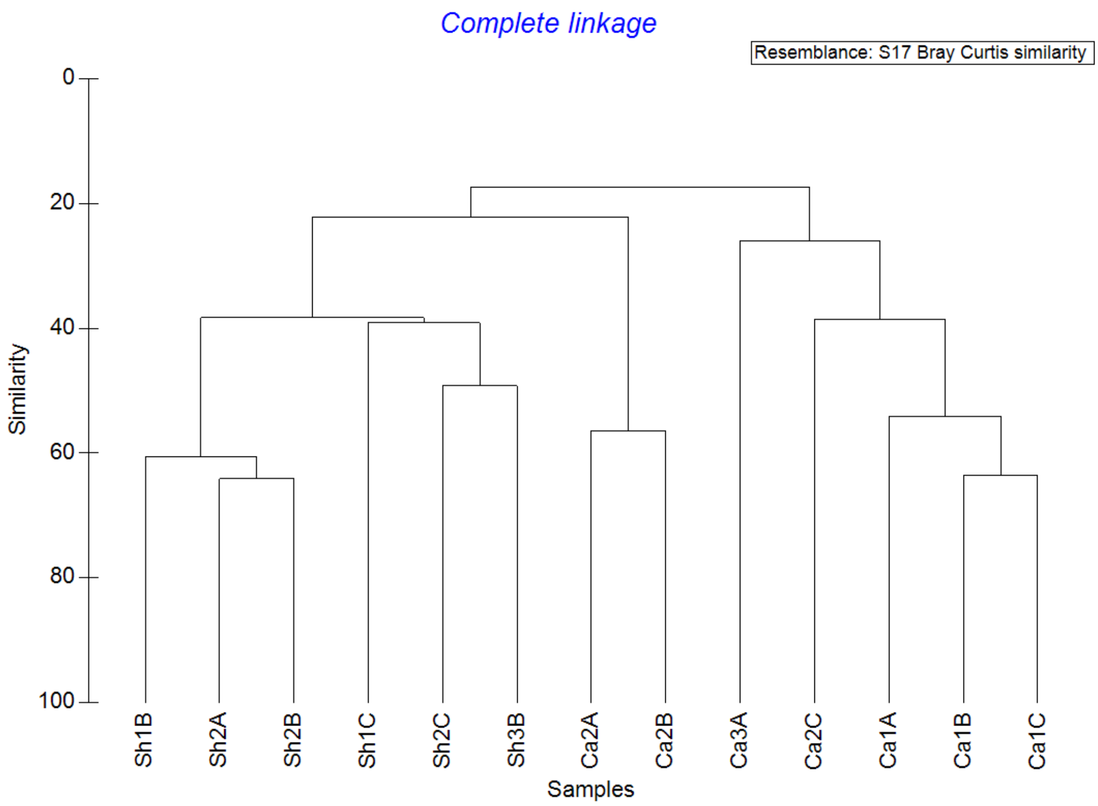

Figure 1. Hierarchical classification of the samples

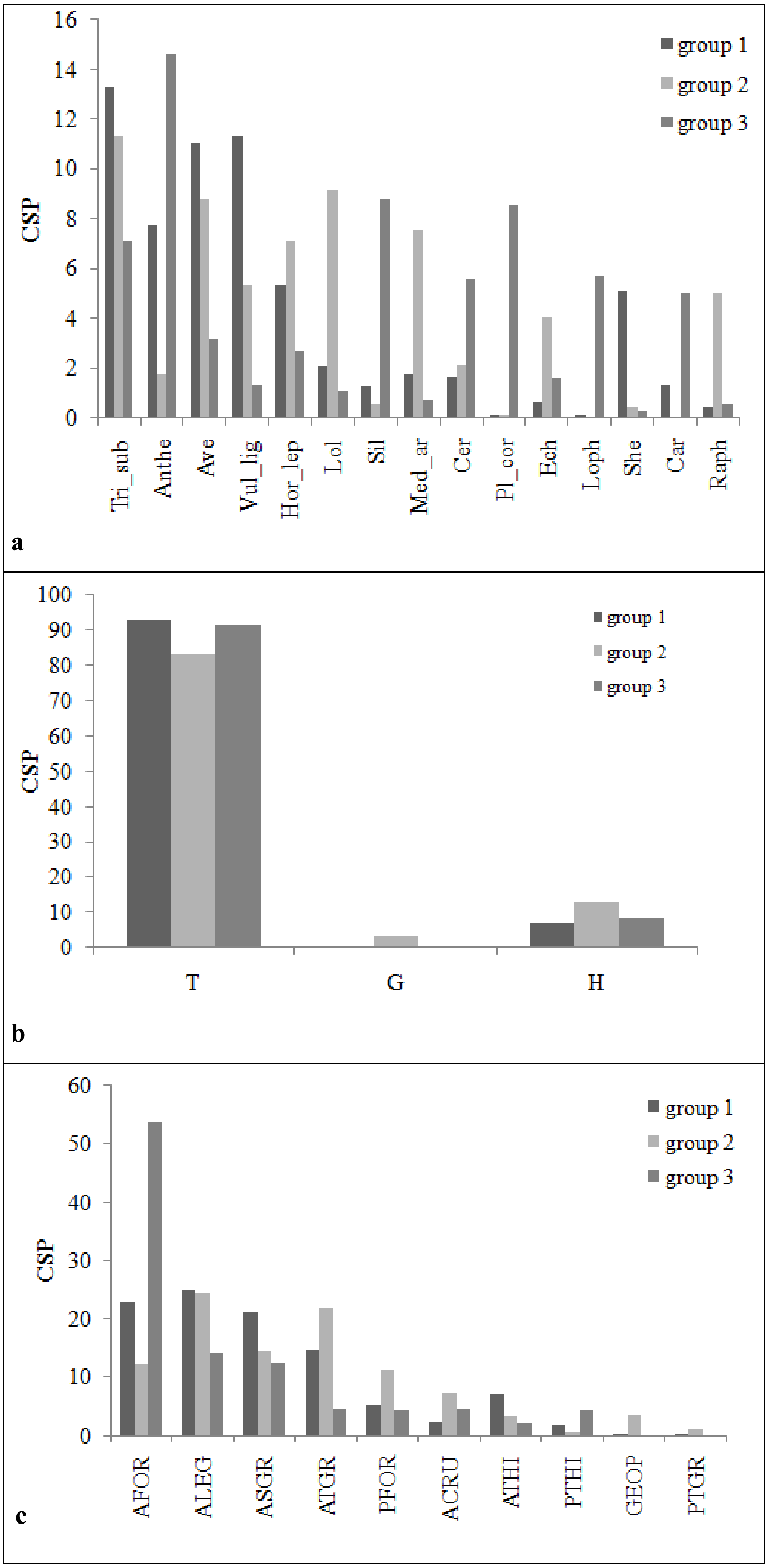

Figure 2. CSP of the most abundant species(a), life form(b) and functional groups in the clustered groups.

3.2 Assemblage parameters

Richness and diversity presented similar values in the three groups (Table 2).

A strong difference (p=0.006) was found in grazing value, group 3 presenting a lower value than group 1 and group 2 (Table 2). In sheep grazed fields (group 1) a positive correlation was found between *Trifolium subterraneum* CSP and grazing value (r_p= 0.76; P<0.05) while in cattle grazed fields (group 2 and group 3) grazing value was positively correlated with *Lolium rigidum* CSP (r_p= 0.87; P<0.01).

Table 2 - Comparisons between assemblage parameters. Mean values in the same row followed by the same letter do not differ significantly according to the MDS test.

	group 1	**±sd**	**group 2**	**±sd**	**group 3**	**±sd**
Richness	64.7	±6.2a	56.2	±10.8a	64.0	±2.8a
Diversity	4.2	±0.3a	4.2	±0.3a	4.4	±0.0a
Grazing value	42.0	±7.9a	49.4	±4.9a	26.4	±2.0b

3.3 Relationships between plant assemblages and environmental and management variables

The CCA triplot (Fig. 3) consistently confirmed the separation of samples in 3 groups. The factor which most affected the assemblage composition was the type of grazing livestock (P=0.008, 19% of the variance explained). The second factor in order of importance was SOC (P=0.05, 14% of the variance explained). Axis 1 was predominantly a SOC gradient. Thus, the richest fields of group 2 were situated toward the left, and the poorest of groups in the right being group 1 in an intermediate position. Axis 2 was predominantly a “type of grazing livestock” gradient with cattle grazed fields situated above and sheep grazed fields below. Then sheep and cattle grazed fields presented a differentiation in species composition but samples corresponding to cattle grazed fields were more variable and indeed split in two subgroups (2 and 3) while the sheep grazed fields formed a very compact group.

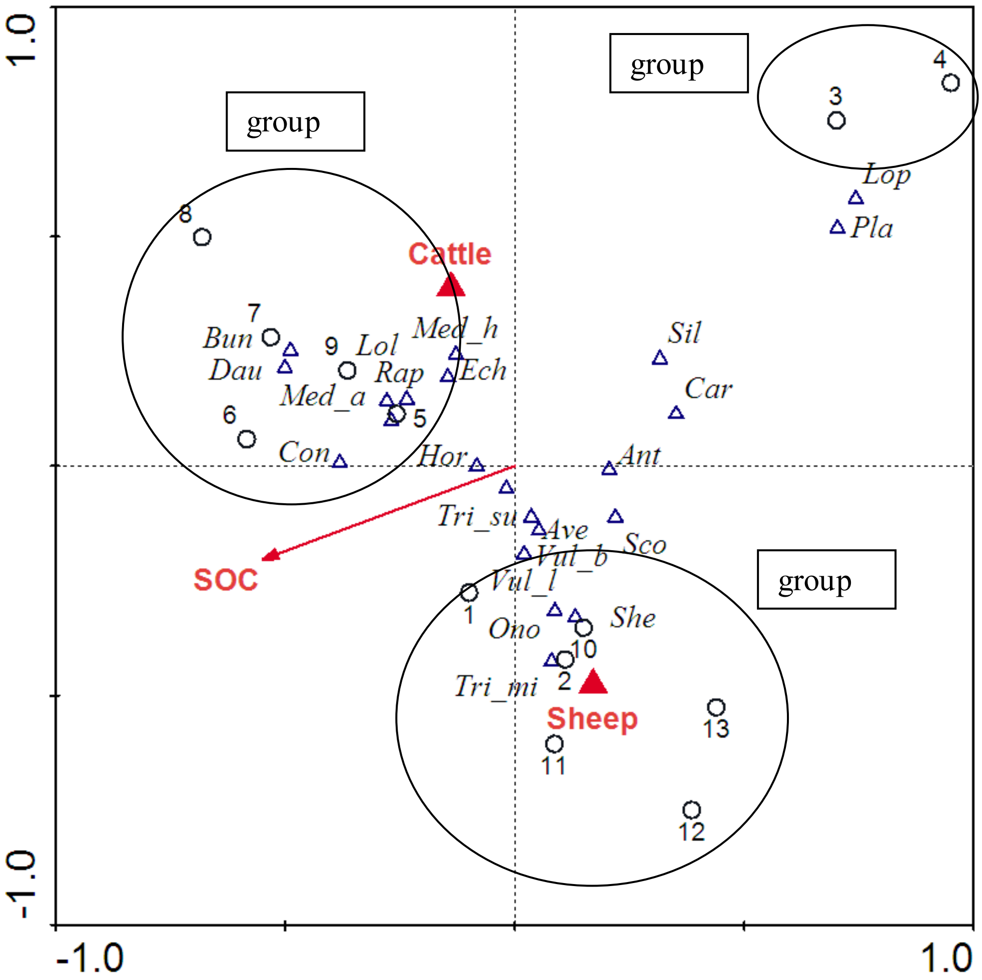

Figure 3. Distribution of samples 1-13 (see table 1 for corresponding field names), species and explanatory significant variables on the firs two axis of CCA.

4 Conclusion

Our results show a variability of plant assemblages in the studied grasslands in term of floristic composition and plant functional types, while the structure of vegetation was substantially uniform. The SIMPER analysis, used to compare the groups pointed out by the cluster analysis in the floristic space, indicated that a large number of species contributed to the dissimilarity among groups and that some of them were among the most abundant in all the groups. This was attributed to the fact that differences among groups were related to a weak balance among few species and to the lack of species belonging to one group only having high cover values.

Overall, the most abundant species was *Trifolium subterraneum*, probably favored by a livestock-resting period in late spring (Garzón-Heydt, 2003), which should be considered a target species for the contribution to biodiversity as well as for pasture grazing values. The biodiversity relevance is associated to its role of characteristic species of the phytolosociological class Poetea bulbosae (Rivas-Martínez, 2002). According to Galan de Mera et al. (2000) and Cano et al. (2007) this class includes Western Mediterranean plant communities adapted to the continuous treading and fertilization and mainly composed by annuals, geophytes and hemicritptophytes. These communities are related to the EU priority habitat type 6220*-Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea (Farris et al., 2007; EC, 1992). The high importance for grazing of this species is due to its high specific index (5), which was assigned to only 5 species of the Sardinian flora (Roggero et al., 2002). The absence of *Poa bulbosa*, which is characteristic of the grasslands associated with *Dehesa* (Olea et al., 2006; Galan de Mera et al., 2000; Cano et al., 2007; Peco et al., 2005), together with a high dominance of *Trifolium subterraneum,* is a peculiar aspect of all the studied assemblages. This was interpreted as being related to the concomitance of different factors such as tillage practices, being *Poa bulbosa* linked to dry conditions and over-grazing in unmanaged conditions (Volaire et al., 1990). Nevertheless, this may be considered an advantage from the agronomic point of view, because *Poa bulbosa* is not as good as *Trifolium subterraneum*, in terms of grazing value (specific index = 2; Roggero et al., 2002). However, the distribution area of *Poetea bulbosae* class is Western Mediterranean and in Sardinia the silicicolus alliance *Trifolio subterranei-Periballion* is described, characterized by the constant presence of *Trifolium subterraneum*, in so far as the north-western side of the island (Galan de Mera, 2000; Cano et al., 2007). In the case study conditions, the eutrophic Poetea bulbosae communities may have been replaced by the oligotrophic communities of Helianthemetea class or mesicolas communities of Stellarietea mediae class (Ladero et al. 1992). So far, the studied community should be considered an impoverished aspect of the Poetea bulbosae class, along the boundary of its distribution area, under sub-optimal trofic conditions.

While *Trifolium subterraneum* was the most abundant species in groups 1 and 2, *Anthemis arvensis* was the most abundant in group 3, which was also characterized by high CSP values of *Plantago coronopus* and *Silene gallica*, both having low specific indices. With the exception of those included in group 3, cattle grazed fields were characterized by high CSP values of *Lolium rigidum, Trifolium subterraneum* and *Medicago arabica*, which provide excellent or good forage (Roggero et al., 2002). *Vulpia ligustica* strongly contributed to the distinguish group 1, from both group 2 and 3, showing a strong linkage with sheep grazing.

The dominance of therophytes in each of the 3 assemblages, with CSP values over 80%, is one of the typical aspects of the grassland communities associated to the *Dehesa* (Olea and San Miguel-Ayanz, 2006) and more generally of the Mediterranean grasslands, where they also represent the main forage source of forage for grazing livestock (Seligman, 1996).

In terms of functional groups, a great variety of therophytes was identified, including AFOR, ALEG, ASGR, ATGR, ACRU and ATHI. The dissimilarities among groups were mainly associated to the AFOR in all comparisons (e.g. group 1 vs 2, 1 vs 3, 2 vs 3). AFOR were most frequent under cattle grazing in the fields with the lowest content of SOC in soil.

Among PTGR only three species, with very low CSP values, were found in the studied fields. This was attributed to the cyclical tillage and the overgrazing which prevent the reproduction of species such as *Dactylis hispanica*, as already observed in Corsica for *Dactylis glomerata* (Volaire et al., 1990). Perennial grasslands dominated by *Dactylis hispanica* are supposed to be the successional stage of development of the vegetation after the cessation of management and grazing inside this environmental unit as already tested in some patches of the landscape completely abandoned since at least 10 years (Bagella et al, unpublished data). Perennial legumes are totally absent probably as a consequence of tillage.

The three assemblage groups did not show significant differences in terms of the biodiversity community parameters, richness and diversity. They are relatively rich in species and presented a high level of eveness.

Even the contingent of good palatable species was very high, grazing value can be considered sufficient in all the groups, being greater then 25 (Argenti et al., 2006; Cavallero et al., 2002). However, group 3 was characterized by a lower grazing value if compared with the other two groups as a consequence of the dominance of AFOR in plant assemblage and the low CSP value of *Trifolium subterraneum* and *Lolium rigidum*, which were the main contributors to grazing value in group 1 (sheep grazing) and group 2 (mainly dairy cattle grazing) respectively.

The analysis of the relationships between plant assemblages and environmental and management variables pointed out the effect of animal grazing on floristic composition. On the contrary, tillage treatments unexpectedly didn't reveal any effect.

In summary, as the target species of these grazing systems, *Trifolium subterraneum*, is weakly favored by sheep grazing we should conclude that the different management schemes adopted in the study area have to be considered similar for its conservation. Further investigation are requested to understand if and how it is possible under such oligotrophic conditions to improve biodiversity quality of this grassland, favoring the occurrence of *Poa bulbosa* and other geophytes that are typical of the 6620* habitat type, that are currently very rare in the area (Bagella et al., unpublished data), but also preserving the relatively good grazing value.

5 References

Aboling, S., Sternberg, M., Perevolotsky, A. & Kigel, J. (2008). Effects of cattle grazing timing and intensity on soil seed banks and regeneration strategies in a Mediterranean grassland. Community Ecology 9 (suppl.), 97-106.

Argenti G, Bianchetto E, Ferretti F, Staglianò N, (2006). Proposta di un metodo semplificato di rilevamento pastorale nei piani di gestione forestale. Forest@ 3 (2), 275-280.

Bacchetta G., Bagella S., Biondi E., Farris E., Filigheddu R., Mossa L. (2004). A contribution to the knowledge of the order Quercetalia ilicis Br.-Bl. ex Molinier 1934 of Sardinia. Fitosociologia 41(1), 29-51.

Bacchetta G., Bagella S., Biondi E., Farris E., Filigheddu R., Mossa L. (2009). Vegetazione forestale e serie di vegetazione della Sardegna (con rappresentazione cartografica alla scala 1: 350.000). Fitosociologia 46 (1), 3-82.

Blasi C., Carranza M.L., Frondoni R. & Rosati L. (2000). Ecosystem classification and mapping: a proposal for Italian landscapes. Applied Vegetation Science 3, 233-242.

Braak CJF, Šmilauer P. (2002). Reference manual and CanoDraw for Windows User's guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, New York, USA.

Bray JR, Curtis JT (1957). An ordination of the upland forest communities of Southern Wisconsin. Ecol Monogr 27, 325-349.

Bullock J.M., (1996). Plants. in W.J. Sutherland Ecological census techniques. Cambridge University Press. Cambridge, 111-138.

Caballero R., Fernández-Gonzáles F., Pérez Badia R., Molle G., Roggero P.P. Bagella S., D'Ottavio P., Papanastasis V.A., Fotiadis G, Sidiropoulou A., Ipikoudis I., (2009). Grazing systems and biodiversity in Mediterranean areas: Spain, Italy and Greece. Pastos 39(1), 3-154

Cano E., Ladero M, García-Fuentes S.A., Pinto-Gomes J.C., Cano-Ortiz A. (2007) Current state of the Poetea bulbosae class in the Iberian Peninsula. Phytocoenologia 37, 3-4.

Cavallero A, Rivoira G, Talamucci P (2002). Pascoli. In: Coltivazioni erbacee. Foraggere e tappeti erbosi. Patron Editore, Bologna, 239-294.

Clarke K.R., Warwick R.M., (2001). Changes in marine communities: an approach to statistical analysis and interpretation (2nd ed.) PRIMER-E, Plymouth, UK.

Clarke KR, Gorley RN (2006) PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth.

Clarke KR. (1993). Non-parametric multivariate analyses of changes in community structure, Australian Journal of Ecology, 18, 117-143.

Daget P. & Poissonet J., (1971). Une méthode d'analyse phytologique des prairies. Critères d'application. Ann. Agro. 22 (1), 5-41.

European Commission, (1992). Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. European Community Gazette 206, 1-50.

Farris E., Filigheddu R., Deiana P., Farris G.A., Garau G. (2010). Short-term effects on sheep pastureland due to grazing abandonment in a Western Mediterranean island ecosystem: a multidisciplinary approach. Journal for Nature Conservation, 18, 258-276.

Farris E., Pisanu S., Secchi Z., Bagella S., Urbani M., Filigheddu R. (2007). Gli habitat terrestri costieri e litorali della Sardegna settentrionale: verifica della loro attribuzione sintassonomica ai sensi della Direttiva 43/92/CEE "Habitat". Fitosociologia, 44, pp. 165-180.

Galán de Mera, A., Morales, R. & Vicente, J. A. (2000): Pasture communities linked to ovine stock. A synthesis of the Poetea bulbosae class in the western Mediterranean region. Phytocoenologia 30 (2), 223-267.

Garzón-Heydt, J., (2003). Recovering trashumance in Spain. In: Transhumance and biodiversity in European mountains. Eds. R.G.H. Bunce ; M. Pérez -Soba ; R.H.G. Jongman ; A. Gómez Sal ; F. Herzog ; I. Austad . Alterra. Wageningen (The Netherlands), pp 259-263.

Joffre, R., Vacher, J., De Los Lannos C., Long, G., (1988). The dehesa: an agrosilvopastoral system of the Mediterranean region with special reference to the Sierra Morena area of Spain Agroforestry Systems 6, 71-96.

Clarke K.R., Warwick R.M.(2001). Changes in marine communities: an approach to statistical analysis and interpretation (2nd ed.) PRIMER-E, Plymouth, UK, 2001.

Koniak G., Noy Meir I., Perevolotsky A. (2009). Estimating multiple benefits from vegetation in mediterranean ecosystems,. Biodiversity and Conservation 18, 3483-3501.

Královec J., Pocová L., Jonášová M., Macek P., Prach K. (2009). Spontaneous recovery of an intensively used grassland after cessation of fertilizing. Applied Vegetation Science 12, 391-397.

Ladero, M., Biondi, E., Mossa, L. & Amor, A. (1992). Los pastizales mediterraneos precedidos por Trifolium subterraneum L. en la isla de Cerden˜ a (Italia). D Doc. Phytosociolgia, 16, 45-64.

Marriott C.A., Fothergill M., Jeangros B., Scotton M., Louault F., 2004. Long-term impacts of extensification of grassland management on biodiversity and productivity in upland areas. A review. Agronomie 24, 447–462.

Montero G., San Miguel A., and Cañellas I. (1998): Sistemas de selvicultura mediterránea: "La dehesa". In: Jiménez Díaz, R.M. and J. Lamo de Espinos (Editors), Agricultura Sostenible. Mundi Prensa, Madrid. pp. 519-554.

Montero G., San Miguel A., Cañellas I. (2000). Systems of Mediterranean silviculture. La dehesa, Grafistaff, Madrid, pp 48.

Noy-Meir I., Gutman M. & Kaplan Y. (1989). Responses of Mediterranean grassland plants to grazing and protection. Journal of Ecology 77, 290-310.

Olea L., López-Bellido R.J. & Poblaciones M.J. (2005). Europe types of silvopastoral systems in the Mediterranean area: dehesa. In: Mosquera, M.R., Rigueiro, A., McAdam, J. (eds) Silvopastoralism and Sustainable Land Management, CABI Publishing.

Olea L. & San Miguel-Ayanz A. (2006). The Spanish dehesa. A traditional Mediterranean silvopastoral system linking production and nature conservation. 1st General Meeting of the European Grassland Federation. Badajoz (Spain). pp. 1-15.

Peco B., de Pablos I., Traba J., Levassor C. (2005). The effect of grazing abandonment on species composition and functional traits: the case of dehesa. Basic and Applied Ecology 6 (2), 175–183.

Peco B., Sánchez A.M., Azcárate F.M. (2006). Abandonment in grazing systems: consequences for vegetation and soil. Agriculture, Ecosystems and Environment 113, 284–294.

Petrella S., Bulgarini F., Cerfolli F., Polito M. & Teofili C. (2005). Libro rosso degli habitat d'Italia della Rete Natura (2000). WWF Italia.

Pielou E.C. (1969). An introduction to mathematical ecology. Wiley, New York.

Pignatti S. (1982). Flora d'Italia, 3 vol. Edagricole. Bologna.

Puxeddu M., Pintus A., Pulina G. (2008). I Meriagos: il confine tra prateria e foresta. http://www.sardegnaagricoltura.it/documenti/14_43_20081014112126.pdf.

Ramanzin, M., Battaglini, L.M., Morbidini, L., Pauselli, M., Pulina, G., (2009). Evoluzione dei sistemi zootecnici e trasformazione del paesaggio. Ital. J. Agron. / Riv. Agron. 3 (Suppl.), 19-23.

Raunkiaer C. (1934). Types biologiques pour la géografie botanique. Bulletin of Academy Royal Sciences. Danemark .

Rivas-Martínez S., Diaz T.E., Fernándo-González F., Izco J., Loidi J., Lousā M. & Penas Á., (2002). Vascular plant communities of Spain and Portugal. Itinera Geobotanica 15 (1-2), 1-922.

Roggero P.P., Bagella S., Farina R., (2002). Un archivio dati di Indici specifici per la valutazione integrata del valore pastorale. Rivista di Agronomia, 36, 149-156.

San Miguel A. (1994) La dehesa española. Origen, tipología, características y gestión, Fundación Conde del Valle de Salazar, Madrid, pp 96.

San Miguel A. (2005) Mediterranean European Silvopastoral Systems. In: Mosquera-Losada M.R., Mc Adam J and Riguero-Rodriguez A. Silvopastoralim and Sustainable Land Management. CABI Publishing, Cambridge, USA, pp. 36-40.

Sebastià M.T., de Bello F., Puig L., Taull M., (2008). Grazing as a factor structuring grasslands in the Pyrenees. Applied Vegetation Science 11, 215-222.

Seligman N. (1996). Management of Mediterranean grassland. In: Hodgson, J. and Illius A.W. (eds), The Ecology and Management of Grazing Systems. CAB International, Wallingford, UK, pp. 359-392.

Sternberg M., Gutman M., Perevolotsky A. & Kigel J. (2003). Effects of grazing on soil seed bank dynamics: an approach with functional groups. Journal of Vegetation Science 14, 375-386.

Volaire F., Godron M., Lelièvre F. (1990). Les formations herbacées de Corse I - Élaboration d'une typologie mésologique et floristique. Agronomie 2 , 163-174.

Winer B.J. (1971). Statistical principals in experimental design (2nd edition). McGraw-Hill, New York.