The Spanish dehesa. A traditional Mediterranean silvopastoral system linking production and nature conservation

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Figure1.- Merino sheep grazing on a typical Spanish dehesa

Abstract

The Spanish dehesa is a traditional, but also up-to-date, Mediterranean agrosilvopastoral system. It might be regarded as one of the most successful and efficient examples of how extensive agrosilvopastoral management is not only compatible with nature conservation and sustainable rural development within its environment, but also necessary for the achievement of both goals. Its area, of about 4 million hectares, is marked by two fundamental features: Mediterranean climate and low soil fertility.

The character, role, management and yield of its major components (tree layer, sward, crops, livestock and wildlife) are described. The current management of the Spanish dehesas is strongly influenced by the Common Agricultural Policy, showing a certain dissociation between the natural environment and its productivity, on the one hand, and agrosilvopastoral treatments, on the other. The main problem affecting the dehesa is the lack or shortage of regeneration of the tree layer.

Keywords: rangeland, Mediterranean, extensive livestock, Nature 2000 Network

Introduction

The term `dehesa' has many meanings. One of them reflects the word´s etymology: *deffesa, defensa*, an early system of grazing land reserved for cattle used for land ploughing. Nowadays, the most widely accepted definition is that of an agrosilvopastoral (or pastoral-silvo-agricultural) system developed on poor or non-agricultural land and aimed at extensive livestock raising (Figure 1). Silviculture is not aimed at timber production but at increasing the crown cover per tree and at producing acorns, browse and fuelwood. 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, covering an area of about 3.5 – 4 million hectares. The greatest part of it is concentrated in Extremadura (1.25 M ha), Alentejo (800,000 ha) and Andalucia (700,000 ha).

The dehesa (montado in Portuguese) is an ancient system: the first written reference is from 924 (Olea *et al*., 2005), though evidence of early dehesas is available from the Neolithic period (Stevenson and Harrison, 1992; Joffre *et al*., 1999). Its expansion is closely linked with historical events: the reconquest of the Iberian Peninsula from the Moors and the subsequent re-distribution of that land, its re-population and the separation of heritages; the role of the Mesta, a powerful association of herdsmen and stockowners, and the sale of Church and nobility lands (Gómez-Gutiérrez, 1992; San Miguel, 1994; Joffre *et al*., 1999).

The typical environment of the Spanish dehesa is marked by two fundamental features: the Mediterranean character of the climate (dry summers and somewhat cold winters) and the low fertility of the soil (particularly P and Ca), making arable farming unsustainable and unprofitable. Another important factor is topography, which is generally flat or hilly, but never rough (Figure 2). Within this difficult environment, the dehesa has arisen as the only possible form of rational, productive and sustainable land usage. It does not try to maximize the output of any particular product. On the contrary, it tries to use a strategy of efficiency and diversification of structures with the aim of taking advantage of every natural resource (multiple, scarce and unevenly distributed in time and space) of its environment with a minimum input of energy and materials. Due to that diversification and efficiency, the dehesa is also a very versatile system and has been able to successfully satisfy human requirements from the Middle Ages up to the twenty-first century. That is the secret of its survival.

Figure2.- The typical Spanish dehesa usually shows a flat or hilly topography

The link between the high structural and biological diversity of the dehesa and its efficiency and stability is the high diversity of relationships between its components. They are so closely entangled by that net of inter-relationships that the management of every single component necessarily affects each of the others. That is why the dehesa system should be described from a holistic point of view as a whole macro-organism; and why the dehesa is a paradigm of equilibrium and mutual dependence between production and nature conservation. Its high environmental value is a consequence of its extensive, integrated and efficient management. Therefore, that management should be considered as a powerful conservation tool (Gonzalez and San Miguel, 2004).

Structure and Management

Due to its large area and its high economic, social and environmental importance, there is much available information on the dehesa system. However, most of it is written in Spanish and, what is even worse, deals exclusively with one or few of its components. Foresters deal almost exclusively with the tree layer but less with livestock or agriculture; agronomists, with crops but not with trees or wildlife; experts in animal production, with livestock but not with trees or wildlife; biologists, with flora, fauna or biodiversity but not with management, and so on. As a consequence, the aim of this paper will be to give a comprehensive view of the whole dehesa system, integrating the management of its different components and environmental aspects. To achieve that goal, we will present the essential information of every component as tables in which we describe the major role of each component and their essential features, regarding composition, production, management and improvement, as foresters do in silvopastoral management projects.

The tree layer

The dehesa is a savannah-like open woodland (with summer drought instead of summer rainfall, as the in true savanah) where trees play a fundamental role of general stabilization providing the so-called services or indirect benefits (Figure 3). However, they contribute to the direct general production of the dehesa with acorns, browse, fuelwood, cork, edible fungus, pollen and some more resources. Its major features are summarized in Table 1. The tree layer is an essential component of the dehesa system and, as a consequence, sustainable management must be concerned not only with adult tress but also with their natural regeneration.This is the most important problem of the dehesa system, since natural regeneration is usually absent or scarce. The almost complete abandonment of transhumance, a partial substitution of sheep by cattle due to the shortage of shepherds, the increase of stocking rates and grazing periods allowed by socio-economic improvement and the Common Agricultural Policy are the most important reasons for that situation. In addition, it is getting worse as a consequence of the accelerated disappearance of adult trees due to the so called `seca´ (sudden dying-off caused finally by a fungal disease and promoted by climatic, edaphic and biological reasons) (Figure 4).

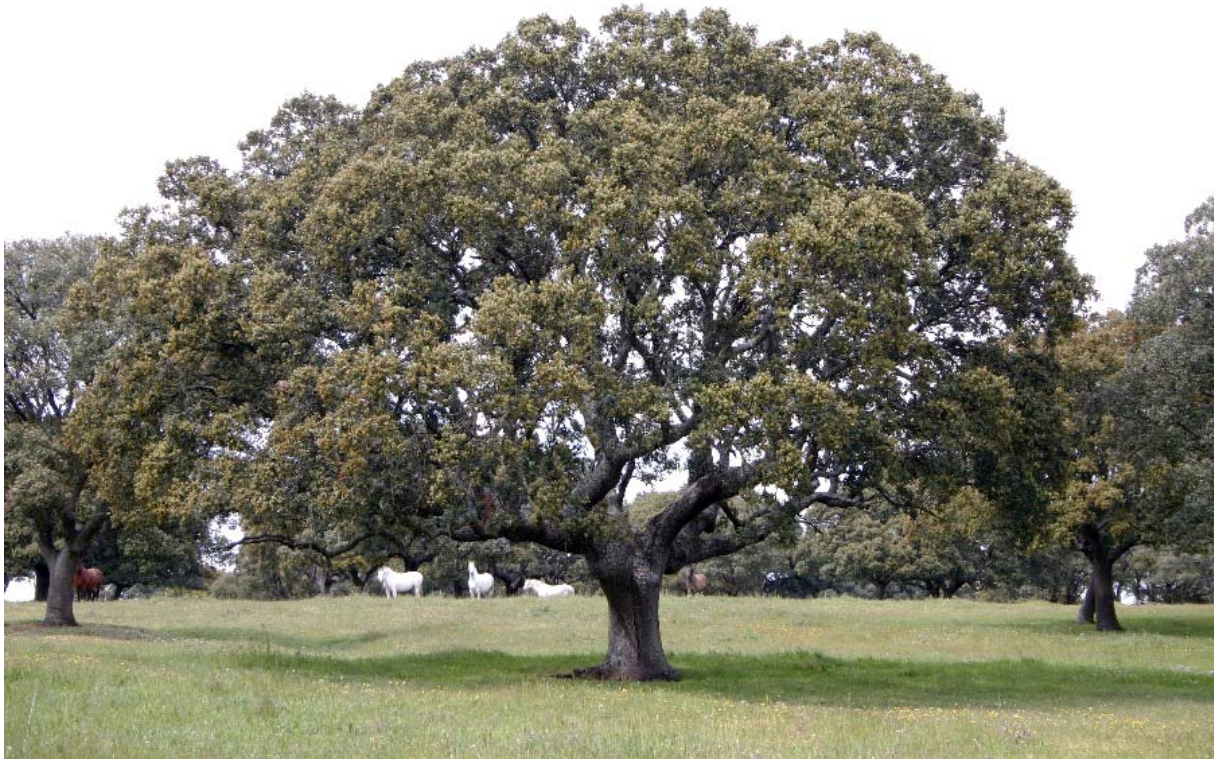

Figure3.- Typical holm oak (Quercus ilex rotundifolia) Spanish dehesa. The scatttered, sclerophyllous and perennial tree layer results in a high diversity of the herb layer. The shrub layer is usually absent or scarce.

Figure 4.- The so-called `seca´ (sudden dying-off of trees) is accelerating the disappearance of the dehesa tree layer.

Table 1.- Major features of the dehesa tree layer and its management

TREE LAYER	Major role	STABILITY: structure, landscape, climate (Joffre and Rambal, 1988, 1993), erosion, water and nutrient cycles, shelter, biodiversity, C fixation, cultural benefits, fodder,...). Perennial sclerophyllous species might be considered as permanent fodder reserves for livestock and wildlife
	Species	*Quercus ilex rotundifolia (=Q.ilex ballota), Q. suber* (sclerophyllous and perennial), *Q. faginea, Q. pyrenaica* (semi-deciduous) and other less important species.
	Density	(15) 20 – 100 (200) adult trees/ha
	Crown	(5) 10 – 50 (70)%
	Basal area	2 – 10 (15) m^2/ha
	Products: Mean annual yield	Fuelwood: 800-5000 kg/ha-rotation (DM) Browse (pruning or direct browsing): 400-1500 kg/ha (DM)(pruning). Direct browsing is important in coppices (usually cold dehesas, with low acorn yield) Acorn: (100) 200 – 600 (800) kg/ha, with inter-annual variations (Olea *et al.*, 2004; López-Carrasco *et al*., 2005) Cork (only *Q. suber*): 500-1500 (2000) kg/ha-rotation
	Silvicultural rotations	Regeneration felling: tree senescence (150 years for *Q. suber* and 250-300 years for other species) Pruning: 10-15 years Debarking: 9-12 years
	Threats	The lack or shortage of natural regeneration of trees in many dehesas is by far their most important threat. Besides, it is getting worse due to the sudden dying-off of many trees known as `seca´.

Natural pastures

The most important objective of the dehesa is extensive livestock rearing. Therefore, natural pastures, as the main source of fodder for livestock, are an essential component of the system. As a consequence of the Mediterranean climate, natural pastures are usually annual grasslands (Figure 5). However, perennials play a fundamental role in valley bottoms and particularly in dense swards created and maintained by intense and continuous grazing, known as majadales. Their major features are summarized in Table 2. The management of natural pastures is aimed at increasing their quality (legumes: protein, minerals), since quantity is much less important due to high variability (up to 200 %, according to Olea *et al*., 1989) and the typical uneven seasonal distribution of their production (Figure 6). Therefore that management is based upon three fundamental topics: rational livestock grazing, legumes and phosphorus. A suitable management might result in a significant improvement of the quality of natural pastures (Table 3). However, seasonal periods of shortage of fresh fodder can not be avoided, so browse, fruits (particularly acorns), crops and supplementary food also contribute to a suitable nutrition of livestock in hunger periods: summer and winter. The shrub layer is typically absent or sparse.

Figure 5.- Annual grasslands usually dominate the herb layer of the typical Spanish dehesa.

Table 2.- Major features of the dehesa natural pastures

NATURAL PASTURES	Major role	Providing fodder for livestock
	Communities	Usually annual grasslands: Helianthemetalia, Thero-Brometalia, Sisymbrietalia. Edapho-hygrophilous perennial grasslands (*Agrostietalia*) grow on valley beds and wither in mid-summer. The optimum grassland community is the `majadal' (*Poetalia bulbosae*), a dense sward of annuals and perennials with a rather high representation of legumes (protein) created and maintained by intensive and continuous livestock grazing.
	Production	1000-2700 kg/ha yr (DM). Majadal pastures usually around 3000 kg/ha-yr DM, with early growth start in autumn and late withering.
	Yearly distribution of the fresh fodder yield	Spring: 60-70% Summer: 0% Autumn: 15-25% Winter: 5-15% Highly variable due to a very high climatic variability
	Management goals	Legumes are essential due to their protein supply but also because, after withering, their nutritional quality is high enough to satisfy the maintenance requirements of livestock. Supplementary feeding could then be avoided or reduced (Olea *et al*., 1989; Olea and Viguera, 1998).
	Improvement	Sustainable but intensive grazing aimed at increasing the pasture quality and at recycling limiting nutrients P fertilization (25 to 35 kg/ha P_2O_5/ha during the first year and 18 - 25 thereafter) aimed at favouring legumes, whenever their abundance is high enough to ensure good results (Moreno *et al*., 1993, 1994). The available P level should be high enough: 8-12 ppm, Olsen method (Granda *et al*., 1991). Superphosphate is the usual product, but natural phosphates (ecological products) are also showing good results (Olea *et al*., 2005)

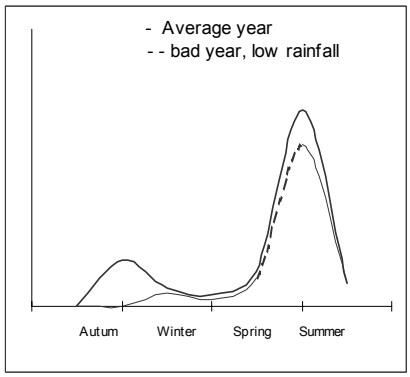

Figure 6.- Annual production of natural pastures.

Table 3.- Nutritional quality of the dehesa natural pastures

Net protein			O.M.D.			% of Legumes		
Max	Min	Average	Max	Min	Average	Max	Min	Average
14.8	8.5	10.3	63.3	40.0	55.2	24.0	4.0	8.5

O.M.D.: Organic Matter Digestibility

Crops, including sown pastures

Crops and sown pastures often play a fundamental role in livestock feeding, as a complement to natural pastures, both in seasonal distribution (summer and late winter) and in quality (Joffre *et al*., 1988) (Figures 7 and 8). In addition, cropping is usually carried out in cycles of several years (3-6) with the aim of keeping intolerant invading shrubs out of natural grasslands. Some dehesa owners allow other farmers to cultivate their dehesas for free when their natural pastures are being invaded by intolerant shrubs, usually *Cistus* sp. The major features of the dehesa crops and sown pastures are summarized in Table 4.

Figure 7.- In the typical Spanish dehesa, cropping is usually carried out every 2-5 years with a double aim: providing food for livestock or humans and fighting against the shrub invasion of the herb layer.

Table 4.- Major features of the dehesa crops and sown pastures

CROPS	**Major role**	Complementing the fodder yield of natural pastures, both in seasonal distribution and quality
	Types	Cereal crops: oat, barley, rye, wheat, triticale. They complement the fodder yield of natural pastures both in seasonal distribution (summer, late winter) and quality (energy). Grain is the most valuable product. It is usually collected, but it may also be harvested by direct summer grazing, since transhumance is no longer being carried out. Straw is also collected or grazed. Sometimes, there is a late winter grazing period of leafy biomass followed by a resting season until the summer grain harvest. Sown pastures. Aimed at being used by grazing or cutting. In the first case, legumes are essential, so subterranean clover (*Trifolium subterraneum*) and other auto-reseeding legume species are the basis for permanent sown pastures (Olea *et al*., 2005). They complement the fodder yield of natural pastures in quality (protein) and, to a lesser degree, in seasonal distribution (air dry biomass and seeds). In the second case, vetch-cereal (oat, triticale, barley), with a 3:1 weight rate and conservation as hay, is the usual choice. However *Lolium multiflorum* and winter cereals are also a choice. Hay is used as summer and winter fodder.
	Production (average climatic year)	Cereal crops: grain (1000-3000 kg/ha), straw (2000-5000 kg/ha) Sown pastures: Legume rich permanent pastures: around 3000 kg/ha (DM) Vetch-cereal: 3000-6000 kg/ha (DM). Hay making
	Management	Two-three tilling treatments before sowing (late winter, late spring, early autumn) Early autumn sowing Fertilization: Cereal crops: N-P-K usually 200-300 kg/ha (8-24-8 or 15-15-15) Legume rich permanent pastures: P (at least 35-40 kg P_2O_5/ha before sowing) Vetch-cereal: N-P-K usually 200-300 kg/ha of 8-24-8 Legume rich permanent pastures should be sown only when natural pastures show a very low abundance of legumes. In any other case, P fertilization becomes a better option.

Figure 8.- Sown pastures are aimed at complementing the fodder yield of natural pastures, both in quality (usually protein, with legumes) and in seasonal distribution (usually cereals).

Table 5 compares the yield (quantity and quality) of natural pastures, P fertilized natural pastures and P fertilized sown pastures.

Table 5.- Production and quality of natural pastures, P fertilized natural pastures and P fertilized sown pastures at the dehesa system of Badajoz (Extremadura, Spain)

			Quality (%)		
		Average response	**Net protein**	**O.M.D.**	**Legumes**
Natural pastures	1440	-	10.3	52.0	8.5
P fertilized natural pastures	2238	55%	11.0	58.9	18.0
P fertilized sown pastures	2670	86%	13.6	62.5	30.0

O.M.D.: Organic Matter Digestibility

Livestock

Extensive livestock is the most important direct product of the dehesa, but also a fundamental tool for creating and improving natural and sown pastures and for dispersing their seeds (Malo and Suárez, 1995; Malo *et al*., 2000) and fertility (Gómez-Sal *et al*., 1992). As a consequence, sustainable and extensive livestock management is an essential tool for the preservation of the dehesa system and its biodiversity. However, it should be compatible with the presence and regeneration of the tree layer, since trees are browsed and damaged by livestock with different intensities (trees up to 12-15 cm of diameter at breast height, or 20-40 years of age, might be shattered by cattle, especially if they are fed with concentrates including urea). Due to the high diversity of the dehesa system, different livestock species are required (Figure 9). The major features of the dehesa livestock and its management are summarized in Table 6.

Table 6.- Major features of the dehesa livestock

LIVESTOCK	**Major ro**	The most important direct product
	Species (breeds)	Cattle: avileña-negra ibérica, morucha, retinta, lidia, blanca cacereña, berrenda en colorao, berrenda en negro, atigrada de Salamanca, ... Sheep: merino, Ille de France, Fleischschaff, Landschaff, ... Swine: Iberian pig (negro lampiño, negro entrepelado, colorado,...) Goat: verata, retinta, serrana,... Horse (español,...); Donkey (andaluz,...)
	Sustainable stocking rate	Cattle: 0.2 – 0.4 /ha Sheep: 2 – 4 /ha Goat: 2 – 3 /ha Iberian pig: 0.4 – 0.6 /ha The usual management is with several species, each one taking advantage of the optimal usage of specific natural resources (e.g. Iberian pig is preferred for fall and early winter acorn yield) An even distribution of livestock is desired with the aims of reducing damages to the tree layer, increasing the efficiency of grazing and reducing the prevalence of parasites and diseases
	Management	Periods of high nutritional requirements of livestock (late pregnancy and lactation) should coincide with seasons showing peaks of fresh fodder supply. Cattle: desired calving season from November until March, depending on winter cold. Lactation: 5-6 months Sheep-goat: two systems. One lambing season/year: spring or autumn (better prices). Three lambing seasons/ 2 years. Lactation: 45 days. Iberian pig: two farrowing seasons/year: spring and autumn (López-Bote, 1998). Piglets born in autumn are fed for one year (to reach 90-110 kg live weight) and then they are fed on acorns and grass from October until January, gaining around 0.7 kg/day (to reach 140-160 kg live weight)

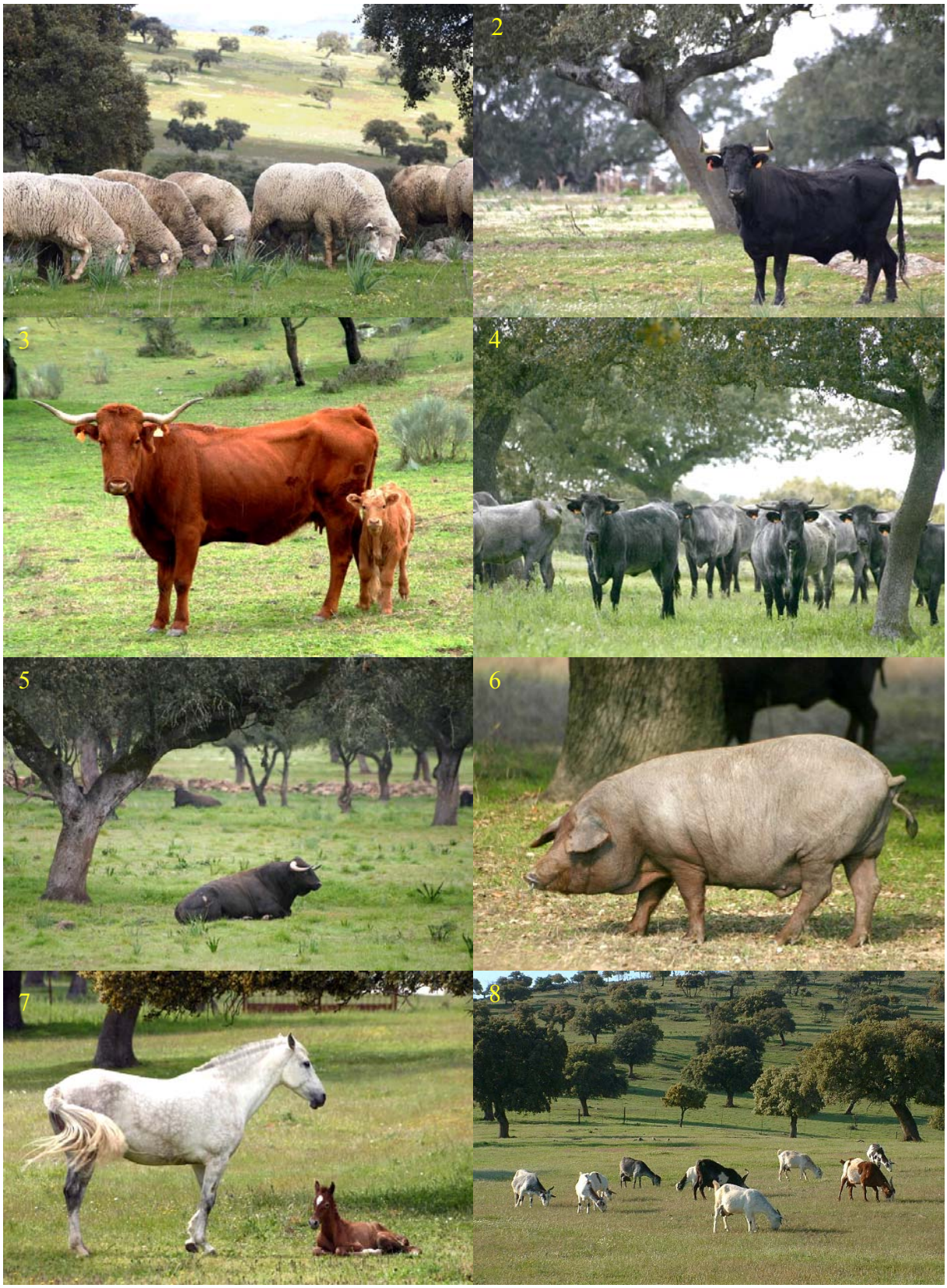

Figure 9.- Major livestock species and breeds of the typical Spanish dehesa. The most important one is the merino sheep (1). However, cattle numbers have increased during the last decades. The most important cattle breeds are aveileña-negra ibérica (2), retinta (3), morucha (4) and lidia (bullfight) (5). The Iberian pig (6) is the most important species for warm dehesas providing high acorn yields. The Iberian horse (7) is being raised for sport and leisure. Finally, the goat (8) is used for shrub control and milk production.

Hunting species

Hunting species have always been present in the dehesa system, but in low densities (with the exception of wild rabbit) since they were considered only as a source of complementary food. However, since 1960s the situation changed dramatically because hunting became a major economic activity and now is often the most important one in many dehesas.Wild ungulates, especially red deer (*Cervus elaphus hispanicus*) and wild boar (*Sus scrofa*), are now regarded as expensive renewable natural resources (Figure 10), so dehesa owners have usually fenced their properties. The result is a dramatic increase of wild ungulate densities (usually over 50 red deer individuals/km^2). This has given rise to a new problem of sustainability (because of impacts on woody vegetation and fauna, prevalence of parasites and diseases which may affect livestock and even man, genetic loss,...) and new concepts of land use (Vargas *et al*., 1995; San Miguel *et al*., 1999). Wild rabbit densities have suffered a dramatic decrease because of myxomatosis, viral haemorrhagic disease and predators (wild boar included). This has become a major environmental problem (Villafuerte *et al*., 1995; González and San Miguel, 2005), since rabbit is the basic prey of many predators (Iberian imperial eagle and Iberian lynx included) and necrophages (e.g. black vulture). Red legged partridge, another traditional hunting species, is also endangered by many problems including the common introduction of farm-raised individuals (with their parasites, diseases and sometimes different genetic heritage) and predators (wild boar also included). Finally, wood-pigeon densities have increased, even though they compete with livestock (especially Iberian pig) and wild ungulates for acorns. The major features of the dehesa hunting species and their management are summarized in Table 7.

Figure 10.- The Iberian red deer (Cervus elaphus hispanicus) is the most important big game species of the typical Spanish dehesa.

Table 7.- Major features of the dehesa hunting species

HUNTING SPECIES	**Major role**	The most important direct product in many cases
	Species	Wild ungulates: Red deer (*Cervus elaphus hispanicus*), wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*), fallow deer (*Dama dama*), mouflon (*Ovis ammon musimon*) Wild rabbit (*Oryctolagus cuniculus*), hare (*Lepus granatensis*) Red legged partridge (*Alectoris rufa*), wood pigeon (*Columba palumbus*), turtle-dove (*Streptopelia turtur*) and some more
	Sustainable stocking rate	Ungulates: 10-20 ind/km^2 Problems of overstocking Wild rabbit: traditionally over 10 ind/ha. Nowadays it has disappeared from many dehesas and their densities are much lower. Red legged partridge: densities vary with food and shelter supply Wood-pigeon: high densities in autumn and winter there where acorn yields are high. Estate owners often scare them with the aim of reserving acorns for livestock or wild ungulates.
	Management	Wild ungulates: usually `montería´ (individuals are driven towards concealed hunters by dogs and dog handlers), but also, in a lesser extent, trophy-stalking. Culling: about 15-20% with the exception of wild boar (higher, up to 100% or even more) Lagomorph and bird species: stalking. Red legged partridge is also hunted by `ojeo´ (individuals are driven towards concealed hunters by people).

Environmental quality

The dehesa is a system protected by the 92/43/EEC Habitat Directive, and included in the Nature 2000 network. In addition, it provides a wide variety of services, or environmental benefits: structural and biological diversity, environmental stability (erosion, climate, nutrient and water cycles, fire,...), landscape, leisure activities, tourism, cultural heritage and some more (Table 8). It is also the habitat of many protected animal and plant species and communities (Figure 11). As a consequence, in spite of the fact that it is usually a private property, the environmental quality of the dehesa system should be considered as a fundamental objective of its management and results in the so-called environmental rent (Campos *et al*., 2001). However, as we stated above, that high environmental quality is a consequence of its extensive, integrated and efficient management and, therefore, that management should be considered as a powerful conservation tool.As an example of it's importance agro-silvo-pastoral management is a basic activity of three LIFE Projects aimed at the conservation of Iberian lynx, Iberian imperial eagle, black vulture and black stork (Gonzalez and San Miguel, 2004). The conclusion is that this kind of management, whose profitability is usually low, should be supported by European, Spanish and regional governments.

The tree crown coverage and distribution has shown to be a major factor in determining the diversity and population density of many animal groups in the dehesa system. It is widely known for livestock species, ungulates, small mammals and birds, but has also been demonstrated for lizards (Martín and López, 2002), ants (Reyes *et al*., 2003) and dung-feeding beetles (Galante *et al*., 2001).

Figure 11.- The typical Spanish dehesa (1) is already a system protected by the European Directive 92/43/EEC . However, it also includes many protected species and communities. Some of the most widely known are the Iberian lynx (2), the Iberian imperial eagle (3), the black vulture (4), the crane (5) and even the Iberian Cabrera´s vole (6). It also helps to maintain and increase the environmental quality thorugh the preservation of the traditional livestock routes (vías pecuarias), and therefore the conectivity between many Iberian ecosystems (7). Finally, it contributes to the preservation of a huge cultural heritage, with traditions such as the pass of trashumant sheep herds trough Madrid(8).

Table 8.- Major aspects of the dehesa environmental quality

ENVIRONMENTAL QUALITY	**Major role**	The most important service or indirect benefit of the dehesa system. Demanded by society and considered as a fundamental goal by every public policy (European Community, Spain, Authonomic Communities), even though most dehesas are private estates. The so-called environmental rent of the dehesa is very high and is still increasing (Campos *et al*., 2001)
	Endang fauna	Iberian Imperial Eagle (*Aquila adalberti*), *Hieraaetus fasciatus,Elanus caeruleus*, Iberian lynx (*Lynx pardinus*), black vulture (*Aegypius monachus*), black stork (*Ciconia nigra*), crane (*Grus grus*), Cabrera´s vole (*Microtus cabrerae*) and many others, invertebrates included
	Other environ service	Structural and biological diversity: α, β, γ Environmental stability: erosion (Bernet, 1995; Olea *et al*., 2005), climate (Joffre and Rambal, 1988, 1993), nutrient and water cycles (Gómez-Gutiérrez, 1992), fire,... Genetic biodiversity: traditional livestock breeds, traditional varieties of agricultural species, ecotypes of pasture species selected by grazing over centuries. Landscape Cultural heritage

The tree crown coverage, as well as the percentage of land covered by natural or sown pastures or shrubs, is also closely related with erosion in the dehesa system (Maldonado *et al.,* 2004). The arrival of autumn rainfall is the worst season from the point of view of erosion risk in the dehesa system, so suitable land use policies (Table 9) may significantly contribute to soil conservation.

Table 9.- Land vegetation coverage

Treatment	November	February	March	April
Fallow (recently ploughed land)	0	0	0	0
P fertilized sown pasture (1st year)	18	76	83	99
Burnt pasture	25	68	79	79
P fertilized natural pasture	82	95	97	99
Natural pasture (unimproved)	70	81	84	90

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