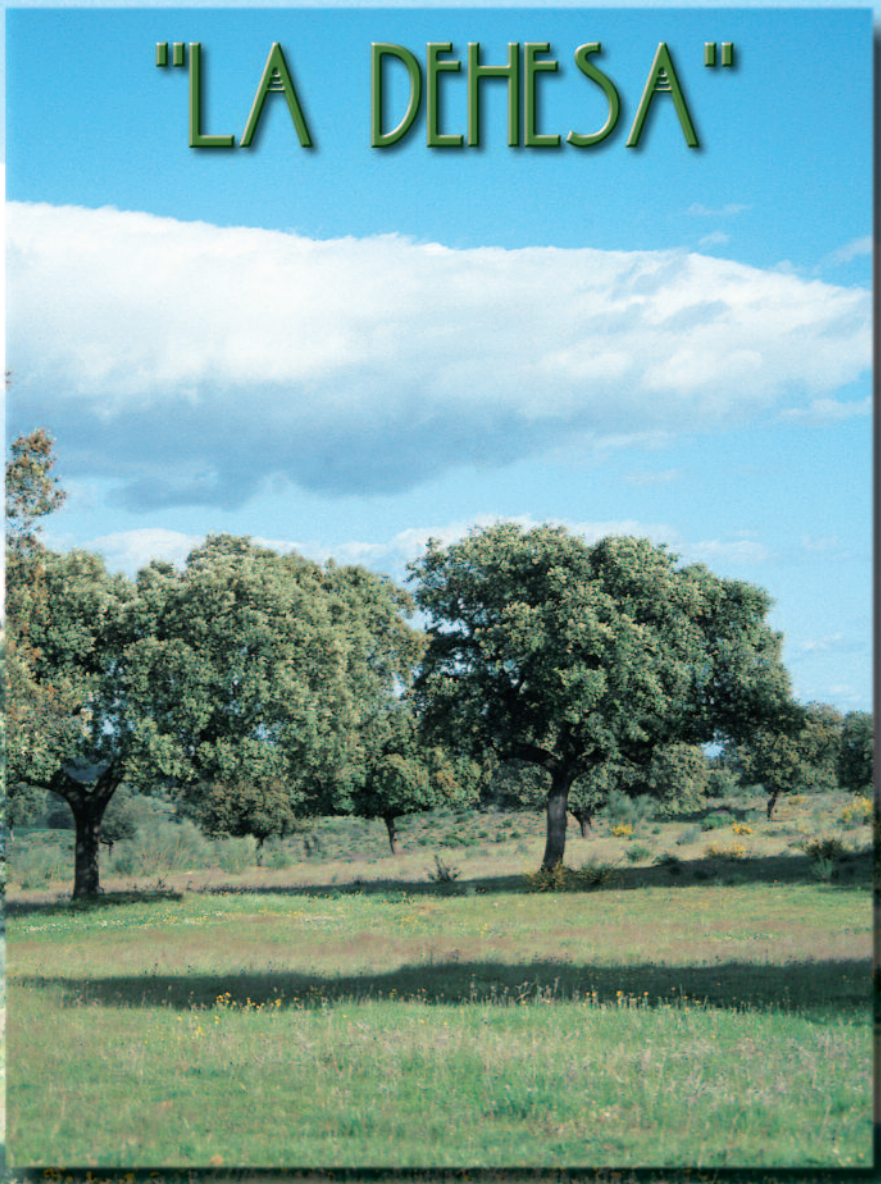
SYSTEMS OF MEDITERRANEAN SILVICULTURE

"LA DEHESA"



G. MONTERO, A. SAN MIGUEL & I. CAÑELLAS

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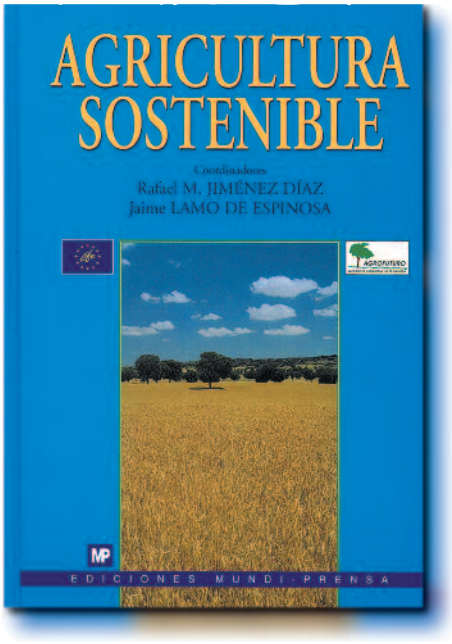
"LA DEHESA"*

GREGORIO MONTERO[1],
ALFONSO SAN MIGUEL[2]
ISABEL CAÑELLAS[1]

[1] Silviculture Department (CIFOR-INIA), Apdo. 8.111, 28080 Madrid, Spain
[2] Silviculture Department, Escuela Técnica Superior de Ingenieros de Montes, Universidad Politécnica de Madrid, Ciudad Universitaria, 28040 Madrid, Spain



*This work is a transcription to English language, with some additional graphic illustrations, of the Chapter 24 (519-554 pp) of the book title "Agricultura Sostenible" co-ordinated by Prof. Rafael Jiménez Díaz and Prof. Jaime Lamo de Espinosa. Co-edited by AGROFUTURO, LIFE and MUNDI-PRENSA in 1998.

This manuscript has been traduced and revised by
Irena Trnkova Farrell (professor of English philology in the
Universidad Politécnica of Madrid) and Charles Farrel (professor
of English philology in Universidad Autonoma of Madrid)

Deposito Legal:
Design and Graphic Production by ANTONIO CRISTO, S. L.
Printed by GRAFISTAFF, S. L.

Summary

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ABSTRACT

This chapter is divided into two different but clearly related parts. Firstly the concept of Mediterranean Silviculture is defined, pointing out the scientific character of this discipline. Its origin, as the result of social necessity, and its functions are analysed. We present a classification of the Silviculture in terms of both the main objective and the intensity of the management. Secondly, we discuss one of the most important forest systems in Mediterranean Spain: a concrete type of open woodland, the *dehesa*.

The dehesa is defined and its origin, typology and characteristics are described. Then its structure and functioning are analysed, taking all its elements (tree, grassland, and domestic and wild livestock) into account, together with the effects these have upon the dehesa system. Its indirect products (stability overall) and direct products (grass, browse, acorns and agricultural crops and subproducts, etc.) are described and the management of dehesa with a view to achieving a sustainable system is also discussed.

Finally, one of the most important problems which affect the sustainability of that management is presented: the scarcity or lack of natural regeneration; possible solutions are analysed.

Key words:
Mediterranean Silviculture, Mediterranean ecosystems, open woodlands, sustainability

The mixing of species, typical of Mediterranean forest systems, helps to increase diversity and to maintain a high rate of biological functionality. In the picture a mix of *Quercus suber* L., *Pinus halepensis* Mill. and *Pinus pinea* L. can be observed. The farmland completes the typical Mediterranean landscape.

DEFINITIONS AND GENERAL CHARACTERISTICS

Forests are one of the most complex units of natural landscape in structure and dynamics. Ever since the beginning of mankind, man has benefited from the products and services (wood, fuelwood, cork, fruits, resin, grazing, hunting, soil protection, esparto, beekeeping, maintenance of wild fauna and flora - in short, biodiversity and stabilisation) supplied by forests. This diversity of benefits stems from its own complexity.

In the beginning, forests were exploited by people according to their needs, neither taking into account their productive capacity nor applying any silvicultural method. The concept of sustainable production - which first appeared with the systematic application of forest management and the foundations of silviculture in the mid 19th century - did not exist then.

In order to obtain the products supplied by forest in an efficient, rational, controlled way, man has developed a technology, an experimental biological science, namely silviculture. This science contains the theoretical basis necessary for understanding the structure and dynamics of the forests, and essential for the designing of the silvicultural treatments to be applied. Some authors (Oldeman, 1990) propose the term Silvology, arguing that natural forests are different from any other terrestrial system due to their size, the longevity of their individuals - especially trees and shrubs - and their degree of complexity; that these systems usually represent the peak of nature; and that they are very different from agricultural or forest cultural systems created by man, managed by clear cutting or in short rotation (*Populus*, *Eucalyptus*, etc.).

Another reason for the importance of silviculture is that it is the only biological and ecological science which has the necessary technology to manage forests, which makes its contents interesting for just a small group of professionals concerned with both technology and biology - almost exclusively forest professionals. This fact, together with the difficulty and the risks involved in its correct application, has caused its omission from science by other biology and ecology professionals, who consider it as a mere simplification of ecology, not as the technification it really is. At other times, owing to ignorance, it has been considered a technique with little biological content, which deserved neit-

her the attention of scientists nor its denomination as a science. Contrary to these conceptions, we think that silviculture and silvopastoralism have contents and peculiarities of a technical and biological kind, not originally exclusive to them, but with a development sufficiently wide and independent from other biological sciences, in which they are not usually represented.

Mediterranean landscape with mixing of forest tree species, scrubland, and another typical element of these systems, the pasturelands, where man and nature are involved in a struggle for survival.

Besides this scientific conception of silviculture, a series of definitions has been developed, highlighting, in one way or another, its applied or technical characteristics, and even the art involved in its practical execution. Shepherd (1986) defines the art of silviculture as the degree of imaginative proficiency through which the forest manager interprets a scientific knowledge within a particular situation. The practical application of silviculture is according to this idea - to find a group of valid prescriptors to apply in each situation. In other words, the general principles are always the same but the method of applications has to change in order to fit certain situations. This is particularly true in the Mediterranean area, where there are no guides or formulae for this highly varied ecological, physiographical and floral environment.

To Daniels and his co-workers (1982) silviculture is - according to the usual definition - "the management or scientific working of forests for their continuous or sustained production of goods and services". However, this brief definition implies many things. Silviculture means more than just using the products a forest offers; it means efficient planning to guarantee real, continuous production of useful goods and necessary services for our present economy. Therefore, silviculture - as we have defined it here - may fail in two ways: firstly, it may not guarantee a continuous yield if the management is incorrect; and secondly, it might go beyond its own objective if the management or treatments applied are so complex that eventually they are more expensive than the yield itself; therefore, the investments and the expected products must be balanced. When applying silvicultural treatments, there must be a strong ecological basis as well as some economic possibilities.

In practice, silviculture is the most essential part of forestal practice or, even, "forestry" - a concept much wider and difficult to limit than that of silviculture. In this sense we could say - following Soares (1988) - that silviculture is, somehow, a group of practices or actions carried out in the forest, whose aim

is to produce a certain behaviour, whichever may be of most importance at any given time: wood yield, environment, recreation, etc. Bearing this in mind, if we want the forest to offer a full range of products, its existence needs to be assured. Thus the concept of "persistence", besides being an essential silvicultural objective, is also an economic goal.

ORIGIN AND FUNCTIONS OF SILVICULTURE

Silviculture appears all over the world as a reaction to the uncontrolled exploitation of the forest. Its aim is regeneration, rational exploitation and controlled harvesting, ecologically compatible with the improvement, persistence and stability of the forest. This statement is endorsed by the evolution of many Spanish forests after applying silviculture for 100 years (Montero *et al.*, 1993) is not the only reason for silvicultural control: a systematic and general control is carried out only when we begin to run out of forest products and the forest itself is being seriously threatened. In this sense, silviculture becomes a social necessity.

Today, if forests exist and are cared about it is not because of their yield - important as this is - but because countries need plenty of well distributed forest areas since these play an essential role in the biological and social balance of the land. This is the reason why society is more and more interested in controlling "where and how" the existing forests are being restored, in which species are being planted in them, and in the harvesting methods used in each case. This social concern about "forestry" is, basically, good for "forestry" and for silviculture. Forest policy cannot be defined only by means of forestry criteria, which are merely a means to an end. The application and diffusion of forestry cannot be considered as an end in itself. Silviculture specialists must guide, explain, and provide information on the ecological and productive functions that forests fulfil, as well as the need to apply silviculture for the conservation and harvesting of man-influenced forests.

Even though wood demand is increasing and reserves are decreasing, the economic importance of the forest is decreasing as opposed to its ecological and recreational importance, and to the need to stabilize the forest and its surrounding systems. Silviculture must take into account this change of use and hierarchy in forest products, seeking flexible methods to optimise these according to social demands, provided that they do not imply irreversible actions or endanger the persistence and stability of the forest. There is a time scale problem here, in that society's preferences change very quickly and silviculture cannot answer its demands at the same speed. From the moment a silvicultural treatment is applied, until the time when a forest positively responds in the way sought, the time spent is nearly always too long for the results to be of interest. Oliver and Larson (1990) express it as "The preferential use of the forest, the knowledge we have about it, management techniques, tools and forest policies change maybe several times from when a tree is plan-

ted until it reaches the age of harvesting". The evolution of the demand for certain goods and services is much faster than the forest's response to silvicultural treatment.

The reforestation of the vegetal cover in degraded areas helps to stop erosion and increase their biological value. The picture shows a reforestation with *Pinus nigra*. The pine has stopped the erosion in some dry ravines (*carcavas*) and enabled a rich riparian vegetation to develop in the stream bed.

Generally, the silviculture of mountain species with high ecological and protective interest is planned in rotations of nearly 100 years, which makes frequent changes of treatment impossible - or at least very difficult. It must be borne in mind that the treatment applied to a forest of a certain age class depends largely on the treatment previously received. Forest yields, by their nature, do not adapt well to sudden changes of orientation without endangering some of the forest's main functions, whether ecological or productive. Silviculture has to be specially careful when giving priority to short-term plans as it might undervalue - or even disregard completely - the most important long-term goals.

EXTENSIVE AND INTENSIVE SILVICULTURE

In silviculture, there are two main courses of action: one called naturalistic or extensive, and the other generally qualified as artificial, intensive, agricultural, productive, etc. coming from the industrial rationalism of the nineteenth century and inspired in agricultural principles (Susmel, 1980). Logically, this distinction is only clear in the extremes, but there is a full range in between. Between pure selection cutting and clearcutting there are many intermediate stands with regular or semiregular structures, which can be adapted to many different ecological circumstances; the point is to choose the best treatment for each circumstance (García Díaz, 1963).

Silvicultural intervention on natural stands, to obtain some benefits, interferes with natural succession or alters the biological balance. This interference can be positive - from an economic point of view, -or negative - from a biological point of view (Toumey, 1947) -. Although one of the objectives of silviculture is to increase any yield that may be obtained from the forest, it cannot for-

get the basic laws regulating natural regeneration, structure and forest growth.

Whenever man has silviculturally managed a forest, its balance has been altered. The silviculture here referred as "naturalistic" strives to keep the natural qualities of the forest, making it compatible with the production of goods and services. The result basically depends on the knowledge about the autoecology of these species and the response that other forests with similar species composition have shown to that particultural treatment. With such knowledge it is possible to obtain a balance between what we could call productive forest and natural forest, suitably co-ordinating ecological and economic principles. The balance we obtain in a silvicultural managed forest with a somewhat irregular structure is - logically - a cultural balance, although it has the main characteristics of the balance reached in non-treated forests, to such an extent, that this special kind of vegetation (which guarantees the survival of the forest and which permits man to obtain maximum benefit from it) has been termed "forest climax" (Ceballos and Vicioso, 1933). In these treatments, silviculture only collaborates with and anticipates nature, forcing some processes in order to obtain yields without sacrificing the biological balance. At the most conservative extreme, silvicultural harvesting replaces the natural forest primary consumers (Cappelli, 1991). This would be the silviculture to be applied in National Parks or other protected areas, carrying out selection cutting in order to sanitate the forest (sanitation cutting), not to extract wood.

Within what we call silviculture, where production makes some sense no matter how naturalistic it is, there can be several types, defined according to their main objective and the grade of control or artificiality of the treatments. We have used these criteria in elaborating the following classification, where the silvicultural treatments are ranked in order from lesser to greater degrees of interventionism:

Silviculture

Its main objectives are protection, persistence and stability as opposed to direct yields. It is understood as a treatment of forest, not of individual trees.

1.- Extensive: based on natural regeneration and with a limited artificial intervention.

1.1.- Protection and ecological and landscape interests predominate over direct yield, which is usually very low (selection cutting).

1.2.- The maintenance of the basic principles of silviculture makes for profitable economic exploitation. It facilitates regeneration measures in difficult areas, while cuttings (generally by means of selection or shelterwood) can be more intense.

2.- Intensive: allowing artificial regeneration, with site preparation in varying degrees of intensity.

2.1.- It has clearly protective and productive objectives with strong support for regeneration. Cutting by any of the types of shelterwood systems. The

concept of the regeneration period is often maintained. Moderate thinning must be applied.

2.2.- The economic objective becomes very important without endangering the basic principles of silviculture. It uses artificial regeneration as a general procedure. Cuttings - by some type of clear-cutting in one or two periods - allow an intense soil preparation. The concept of regeneration period disappears, since this comes immediately after the cutting, giving rise to even-aged stands in each cutting unit area. Medium to long rotations are maintained. A strong thinning regime must be applied in order to obtain the best yield.

Mediterranean silviculture is typically multipurpose because some products are simultaneously managed. In the picture we show a pine wood of *Pinus pinea* which produces wood, kernels, charcoal, and brings hunting and landscape benefits.

ARBORICULTURE

Interest in protection is nearly always maintained, though this does not always outrank productivity. The objective of persistence can be occasionally limited to the rotation period, and the concept of forest stability loses its importance. Cultural treatments - cleaning and thinning - are essential and must be intense.

1.- Extensive: Reforestation techniques are used. The protective function may be important, since locations have poor and steeply-situated soils. Soils are not usually conditioned after planting and fertilisation is seldom considered.

The silvicultural technique permits the sustainable and rational use of forest systems, whether open woodland or not, and maintains their ecological function. In the picture we show a *Pinus pinaster* stand where low thinning has been performed, removing the worse-shaped trees and reserving the better quality ones for final harvesting.

The Mediterranean systems also permit intensive silviculture. In the picture a reforestation with *Quercus ilex* sp. *rotundifolia* mycorrhiza with *Tuber melanospurum* (*Tuber nigrum* Bull.) of 25 years old. Truffle production brings important economic benefits.

2.- Intensive: the planting technique can be very sophisticated and expensive (deep root planting of poplars). Soil preparation, fertilisation and sometimes watering are usual tasks. The protective function may not exist. Rotations are usually short and yields very large.

Silvopastoralism

Its main objective is the control, management and harvesting of a plant community, in which both a higher story - formed by trees-, and a lower story - formed by herbaceous and shrubby species - coexist; or, more generically speaking, a plant community formed by a slow, stable woody structure and a fast growing, short-lived herbaceous one (Montoya, 1983). These two stories or structures are closely related to one another and both must be taken into account when intervening. This does not imply that silviculture and pastoralism loose their own specific features, though each case must be detailed in order to guarantee the perpetuation of the model proposed, the pasture-forest (Spanish "dehesa forest").

Kernel production of *Pinus pinea* in reforestations with selected clones establish a Mediterranean arboriculture which could be economically viable.

1.- Extensive: relative abundance of trees, generally more than 50 trees/ha, or open pastures ("dehesas") which have been thinned and very degraded by repeated tilling and overgrazing, in which cereal or fodder crops are no longer profitable. Based on the balance produced by grazing management. The understorey has many shrubs periodically cleared. Rather than grasslands, these should be called "gra-

zing areas". Acorns, cork or game are more important here than cattle grazing.

2.- Intensive: low tree density. Frequent screefing, labouring and even fertilisation. Cereal and/or fodder sowing. High-yield seasonal pastures (autumn, winter and early spring) which justify the maintenance of the system. Tree yield, though important, is usually subordinated to cattle grazing.

The *dehesa* is a silvo-pastoral system created by man and his livestock, and maintained for and by their use. In summer, the green of the tree crown contrasts with the beige colour of the dry grassland.

AGRO-SILVICULTURAL SYSTEMS

The objective is to keep a profitable balance between "forestry" and agriculture, planting trees along roads, banks, irrigation channels, around crops or houses, or as hedgerows - which can also serve as windbreaks, or even clumps in between which are grown horticultural, cereal or fodder crops. This system, known since the Roman Empire, has been maintained for centuries in countries such as the U.K., The Netherlands, Australia, China, and has now, under the international name of Agroforestry, been given a new lease of life by North European countries. The idea is appealing because wood, fuelwood and landscape can be produced while protecting crops, but problems arise because trees and agricultural crops are in heavy competition. A minimum distance between rows, an orientation to prevent trees from dominating the crops, and densities in the case of clumps with cover crops must be carefully calculated in order to create and maintain as stable a balance as possible between forestry and agriculture. Only by achieving this balance could it be called a system.

These areas or territories have an agricultural base, and "forestry" is only a complement to crops. Silviculture has less importance, but is still essential to achieve the balance of the mixed agricultural-forest system. In our country, this kind of exploitation may increase greatly due to the reforestation of those lands where agricultural crops have been abandoned; this is why this section on agroforestry systems is here included, although traditionally they have been of small importance in Spain. For these systems Matthews (1989) offers the following classification:

1.- Agro-silvicultural: agricultural crops where trees, placed as mentioned above, alternate with or surround farmlands.

The *dehesa* has periodically been cultivated with cereal for grain or other fodder species. This practice, in conjunction with the livestock usage, has been carried out so as to maintain the agro-silvo-pastotal system free from the encroachment of woody vegetation.

2.- Silvo-pastoral: trees provide food and shelter for livestock, which can feed on both the fodder produced in the lands between the tree lines and on the shaded pasture growing beneath them.

3.- Agro-silvo-pastoral: this is a combination of the two above.

4.- Domestic gardens: trees and shrubs around houses. In some parts of Asia these reproduce the structure of a humid forest on a small scale.

In a true Mediterranean environment, the low yield of the systems usually means that the application of costly silvicultural techniques is not feasible as an economic investment, though it may be used as a means to achieving higher aims such as soil protection, the maintenance of biodiversity or fire prevention.

The high degree of ecological sensitivity of Mediterranean systems, and their slow recovery rate after serious disturbances such as fellings, excessive exploitation, overgrazing or fire, mean that silvicultural actions must be well thought-out, measured, and respectful of the systems' dynamic and natural evolution. In markedly Mediterranean climatic conditions it is common or even general that tree height is governed by hydrological conditions. The same can be said about density, which is determined in these areas by competition at root rather than at crown level. In other words, competition stems from lack of water rather than lack of light. Here lies the main practical and conceptual difference between Mediterranean and Central European Silviculture.

OPEN WOODLANDS ("LA DEHESA")

This agro-silvo-pastoral system could be maintained by intensive grazing, managed rationally. Natural regeneration should be achieved in order to guarantee its future.

A particular case of silviculture, or rather agro-silvo-pastoralism, is the Spanish *dehesa*, one of the most attractive and efficient systems, both conceptually and physically, by which advantage may be taken of the varied, though limited and seasonally fluctuating resources found on the poor soils of Mediterranean ecosystems. Given the importance and extent of this system, we can only present an outline of it in this paper.

DEFINITION

The term *dehesa* has many senses. One of these reflects the word's etymology (*deffesa*, *defensa* - an early system of grazing land protected and reserved for domestic livestock used for land ploughing and that belonging to the feudal lords, serving a purpose - as Allue Andrade has pointed out - similar to that of our twentieth-century petrol stations); in this sense the word is applied to the common grazing *dehesas* to be found in nearly all settlements in Spain. Another, more widely accepted definition is that of an agro-silvo-pastoral system of non-agricultural or forestry characteristics, used for stock-raising; this consists of a sparse story of trees, sheltering a herbaceous grazing/browsing story, the precise composition and function of which depend largely upon the former. The K and r y strategies are employed here (see Montserrat, 1975), thus ensuring the stability and productivity of the system. The *dehesa* management is usually complemented by arable farming carried out every 2-5 cycles in a given place. With this, besides producing food or fodder crops, the invasion of grassland by shrubby vegetation, less valuable for livestock (though it disappears with intensive feeding), is held back. Thus another of the typical physical characteristics of the *dehesa* is the absence or sparseness of a bushy story.

The Spanish *dehesa* is thus an agrobiosystem created by man and his livestock, and maintained for and by their own use. If this last factor were to disappear, so would the *dehesa*. It is also, As Margalef (1980) points out, both characterised by the diversity of the different taxonomic groups (flora and fauna)

Cork oak *dehesa* permits the same management as holm oak *dehesa* and may offer a considerable cork yield.

of which it consists, and by its structures and yield (diversities a and b). It is thus a very versatile and stable system, both ecologically and with regard to productivity. Perhaps because of this the *dehesa* has worked efficiently over the centuries, and even today, with technology utterly different from that available at the time the *dehesa* came into being, it is still the most efficient way of making use of the area's natural resources.

Surface

The lack of a precise definition of the concept *dehesa* means that there are no reliable statistics on the area it occupies. Nevertheless, the figures contributed by various authors (ICONA, 1980; Abreu, 1983; Díaz Pineda, 1987; Joffre *et al.*, 1988; San Miguel, 1994) enable us to estimate the area of Spain occupied by *dehesa* as over 3-3.5 million hectares. As to its distribution, it is mainly, but not only, found on oligotrophic soils in Mediterranean Spain. On eutrophic soils most *dehesas* have been replaced by arable farming more suited to these better quality soils. There are also some examples of *dehesa* outside the area of Mediterranean Spain, but these differ markedly in structure, function and management from the typical Mediterranean ones. Most *dehesas*, then, are in the west and Southwest of the Iberian Peninsula.

The environment of the *dehesa*

The typical environment of the Spanish *dehesa* is marked by two fundamental features: the Mediterranean character of the climate and the low fertility of the soil, making arable farming unsustainable and unprofitable. Another important factor is the topography, which is generally hilly. In this difficult environment, the *dehesa* has arisen as the only possible form of rational and productive land usage.

The characteristic tree population in these conditions belongs to the sclerophyllous xerophyte category, with small, thick, perennial (2-4 year) leaves, able to regulate the opening and shutting of their stomata - thereby optimally adapting their transpiration and photosynthetic activity to water availability. The energy cost of forming and maintaining these leaves is high, and their photosynthetic capacity low, since their surface area is small in order to avoid moisture loss through transpiration. Thus the production cost / benefit rate (dry material produced by photosynthesis) is low (Gracia, 1990), and wood growth is slow and irregular. Little usable wood is therefore produced, and what there is suitable only for high fuel quality or charcoal. A purely silvicultural usage was therefore rejected from the earliest times, and the wood thinned in order to obtain maximum diversity and stability in yield.

Ash (*Fraxinus angustifolia*) *dehesa*s are not widespread, but their high grass and browse production permits a high grazing rate.

In the zone dominated by *dehesa*, the pastures are not permanent communities, but rather stages in the substitution of the woodland which have been created and stabilised by grazing, fire and, at times, arable farming. The herbaceous vegetation is typically Mediterranean. However, the most common form of "adaptation" to the Mediterranean nature of the climate is therophytism. Most of the herbaceous species therefore germinate in autumn, bloom, bear fruit and seed at the end of spring and in early summer, stay in seed form throughout the summer, and begin the cycle again in autumn. Most of the serial rangelands in these areas are therefore characterised by a non-pro-

Quercus faginea stands have been managed mainly as coppice in the Mediterranean region. With changes in the type of fuel consumption, firewood has lost importance and the transformation of this coppice to open woodland has increased.

When the *Quercus faginea* coppice has been thinned, grazing with goats helps to maintain the open woodland

ductive summer period, and a winter, too, depending on how cold it is, of low or zero yield. Both of these periods rule out continuous usage, and oblige the livestock which feeds here to seek alternative systems or resources: mountain grasslands, gleanings from farm crops, fruit, browse, prepared fodder, conserves, etc.

The fauna of the *dehesas*, whether wild or domestic, is rich and diverse, reflecting the multiplicity of the ecological subsystems found within them. Furthermore, a large part of the wildlife does not merely exist physically in the *dehesa*, but depends heavily for its very existence on it - in some species the *dehesa* is virtually their only habitat. Such valued species as the Iberian imperial eagle (*Aquila adalberti*), the black vulture (*Aegypius monachus*), the black stork (*Ciconia nigra*), the common crane (*Grus grus*), the black-shouldered kite (*Elanus caeruleus*), and even the Iberian lynx (*Lynx pardina*) are closely linked to the *dehesa*. Domestic livestock similarly associated with the *dehesa* are the Iberian pig, retinto and morucho cattle and merino sheep.

Typology

With regard to the dominant tree species, typical *dehesas* are usually populated by holm oak (*Quercus rotundifolia*), cork oak (*Quercus suber*), and even quejigo oak (*Quercus faginea* sbsp. *broteroi* o *Q. broteroi*) in areas of higher soil humidity. However, there are also *dehesas* of *Quercus ilex*, *Quercus faginea* sbsp. *faginea* and *Q. faginea* sbsp. *alpestris*, *Quercus pyrenaica* and other Mediterranean and sub-Mediterranean oaks (*Quercus canariensis*, *Q. pubescens*), ash (*Fraxinus angustifolia*) and even pines, especially *Pinus pinea*. Other accompanying tree species, though these may be locally important, include wild olive (*Olea europaea*), junipers (*Juniperus oxycedrus* and *Juniperus thurifera*), carob (*Ceratonia siliqua*), etc.

From a functional - and therefore also an exploitative - point of view, another, perhaps more interesting typology can arise, which we shall now consider. In the south, Southwest and west of the Peninsula, in areas with mild winters, acorn production is very important for Iberian pig fattening. For this reason, *dehesas* are usually high forest, with large trees, producing more acorns than coppice *dehesas*, which consist of shoots from stocks and/or root. In high forest

dehesas, the exploitation of mast becomes paramount, while browsing is not very intensive due to the small quantity of browse available to livestock. Perhaps because of this, Montoya's "hidden or distant tree population effect" (the transporting by livestock of the fertility product from browse to distant areas) is relatively small. In the centre of the Peninsula, with similar conditions of humidity but with colder winters, acorn yield is low and sporadic, while firewood and browse are valuable resources. In these conditions it is common to find coppice *dehesas* in which mast is only a complement to livestock diet, while browsing is of great importance, especially in winter. The "hidden effects of tree population" are therefore more in evidence, and the improvement of pastureland by livestock is easier and quicker. Finally, in dryer, and usually colder conditions, *dehesas* are made up mainly of marcescent or deciduous species: rebollo oak, ash, etc. Obviously, in these *dehesas*, the most difficult period for livestock is no longer summer, since there is usually green grass available, but winter, because of the cold. In these conditions the role of the tree population in the functioning of the *dehesa* is less important, due to its low fruit yield, its lack of leaves in winter and to the lower length of the summer drought. Its main functions are the protection of livestock (against heat in summer and, above all the cold in winter), the provision of firewood and browse (the latter mainly at the end of summer), nutrient pumping, and the fulfilling of its role as a diversifying element in the system.

Quercus pyrenaica trees constitute open woodland systems with comparatively high grassland production, due to this species living in areas with greater precipitation than *Q. suber* or *Q. ilex*. Their acorn production may be high in the warm climate sites of southern Spain.

The low density of the *Pinus pinea* stand permits high grass production. These vegetal formations have the typical aspect of a Mediterranean *dehesa*.

Origin

The origin of the Spanish *dehesa* is to be found at least as far back as the middle ages, since there are documented references to its existence over more than a thousand years. Its present state is the result of the combined effects of multiple factors, particularly geographical and historical. The latter, particularly, have been especially significant, including the period of Arabic control in Spain, the reconquest period and its subsequent processes of human resettlement and land redistribution, the influence of the Mesta (an organisation of herdsmen and stockowners powerful, and enjoying great privilege, from the thirteenth to the nineteenth centuries), transhumance (Llorca and Ruiz, 1987), and the foreclosings of the late nineteenth and early twentieth centuries (Gómez Gutiérrez and García, 1987).

The presence in Mediterranean Spain of human settlements on poor soils, and the need to satisfy their need for food from limited, irregular, and seasonally variable resources, is the main reason for the existence of the *dehesas*. The process of their creation and stabilisation is a continual struggle of man and his herds against ecological processes, to stave off the encroachment of wooded rangeland by serial woody vegetation, and to maximise its exploitation. The most important stages in this process are as follows:

Woodland clearing

More or less gradual, depending on the particular case. Fire certainly played a very important role in the first stages of the creation of most of our *dehesas*.

Control of woody vegetation and the stabilization of pastureland

There is evidence that it is possible to control the encroachment of woody vegetation, thus stabilising the pastureland, merely by means of livestock (Etienne, 1977; Montoya *et al*., 1988), but in most Spanish *dehesas* this process has been carried out by repeated joint action of tilling, cereal cropping and livestock usage (Rivas Goday, 1966).

The usual sequence of measures from forest clearing onward may be described in the following way:

Fallowing. Once the wood has been cleared, the land is tilled to rid it of serial woody vegetation and to take advantage of the fertility accumulated in the upper soil horizons.

Arable farming. Generally cereals (oats, barley, wheat or rye; sometimes vetch-oat). Soil poverty only permits crop rotation in cycles of two to five or more years.

Stubble grazing. Once the cereal has been cropped, the stubble is grazed that

same summer and throughout the following year-in which case it will be invaded by serial herbaceous vegetation.

Posío. After cropping, the ubblefield begins to be invaded by autochthonous grassy species, and a pioneer annual grassland is established-subnitrophilous, poor and short-lived-which is commonly called the *posío*. This pastureland is fully grazed over two, three or more years, after which the small increase in soil fertility, and above all the encroachment of woody vegetation, generally lead to another tilling.

Once the wood has been cleared, arable farming gives way to the phases of stubble grazing and *posio*, and the land is divided into fourths. This cycle is successively repeated. In the picture we show the sequence of these four phases.

This cycle, which brings about the partition of the *dehesa* into zones called *los cuartos* (fourths), is successively repeated. However, little by little, small modifications begin to be apparent, including particularly the gradual reduction of the encroachment of woody vegetation, and the improvement of the *posío* as a result of grazing. Thus the cycles show a tendency to lengthen to as much as ten or twelve years, and even to eliminate the tilling stage when livestock can by itself keep down the encroachment of woody vegetation.

Nowadays it is common to find the sowing of subterranean clover, and the carrying out of improvements and fertilisation (Granda and Prieto, 1992) (mainly with phosphates); hence the *posíos* become more productive and of higher quality, thus substituting an arable cereal cultivation of increasingly doubtful viability (Montoya, 1989). The improvement of the *posío*, moreover, makes it a stronger competitor against the invading scrub, and allows grazing to be increased, thereby favouring the stabilisation process of the grassland.

Improvement of grassland

The livestock stabilises and improves the grassland on the *dehesa* and limits the encroachment of woody vegetation, though not in an even manner, since the animals have preferred areas where they spend most of their time. Here we find two overlapping effects:

Tree shade produces a beneficial effect on pasture. In this way, the herbaceous vegetation under the tree cover can lengthen its growing season, beginning earlier and finishing later than that not growing under trees.

Soil improvement by animal droppings. The improvement of soil structure as a result of the addition of humifiable organic material (organic improvement) and nutrient enrichment. The livestock, moreover, acts as a fertility vector (moving fertility from one place to another) and as an accelerator of the nutrient cycle. The increase in humifiable organic material in the upper soil horizons, apart from improving its structure and increasing its capacity for ion interchange, notably increases its moisture retention capacity. Because of this there has arisen the traditional practice of *redileo* (penning), whereby the herd are kept for two or three nights in pens or folds whose positions are constantly varied.

Intensive grazing. If there is no overgrazing, the intense pressure placed on the preferred places of livestock leads to grassing-over, and a strong selection favouring grazable species. Woody species disappear, while of herbaceous species the most favoured are those which are tastiest and of high nutritional value - the most consumed (*pastoral paradox*). This is due to the fact that, precisely because of the pressure of grazing which they have had to withstand over centuries, they have been "obliged" to "develop adaptive mechanisms", such as stolons, rhizomes, creeper characteristics, bulbs or viviparity, in order to be able to resist the grazing herds and to survive. As a result, intensive and continuous grazing, apart from provoking grassing-over, leads to the marked improvement of the grassland.

Structure and operation

In spite of its relatively complex nature, the *dehesa* is not usually self-sufficient: at the very least the feeding of livestock depends on neighbouring systems in periods of scant grazing. We can thus speak of two structures in the *dehesa*, the internal and the external. The internal structure consists of three components: the tree population, the grassland and the livestock. We shall now describe these in somewhat more detail.

The tree population

Livestock seek shade under trees for protection from the sun and heat of summer. In winter, trees protect the extensive livestock from the cold weather. In the picture we show a group of sheep sheltering from the summer heat.

The tree population is an essential component in the *dehesa*. Its operations can be simply conceptualised in two broad, and interrelated, groupings, concerned, on the one hand with stabilisation, and on the other with productivity. With respect to the former, there is an ample bibliography on the ecological role performed by the tree population in the *dehesas* (González Bernáldez *et al*., 1969; Montserrat, 1966, 1974; Escudero *et al*., 1981; Montoya, 1982; Montoya *et al*., 1988; etc). Briefly, the most important effects of the tree cover in the *dehesa* are as follows:

Interception of the sun's rays and water vapour. The mere presence of the treetops of the *dehesa* promotes the maintenance beneath them of a microclimate which is less cold in winter, and, above all, fresher and more humid in summer. In this way, the herbaceous vegetation under the tree cover can lengthen its growing season, beginning earlier and finishing later than that which is not under the trees.

Interception and redistribution of precipitation. The tree cover retains part of the precipitation and redistributes the rest, concentrating it, by dripping, around the trunk and underneath the crown perimeter. The impact on the soil is thereby reduced, while the nutrient content of the water is increased by the washing-off processes of straining and dripping. In this way the recycling of nutrients is speeded up and there is a marked improvement in their usage. This is highly important, above all in the cases of the rarer or more sparsely occurring elements such as P, K, or Ca, whose prolonged "immobilisation" in organic structures would be a too much of a "luxury" for the system.

Various effects on the wind. The scattered presence of trees in the *dehesa* produces a marked reduction in wind speed, and hence the drying effects of wind, with the consequent effects on evapotranspiration and temperature.

Root competition between trees and pasture. In general, the trees of the *dehesas* have not only a system of deep pivoting roots, but also a very wide system of surface roots which compete with those of the pastureland in capturing nutrients and the water from light precipitation.

Tree evapotranspiration. The evaporation from the tree population of the *dehesas* reduces, generally speaking, the humidity content of the upper soil horizons.

Group of horses sheltering from the summer heat.

Organic improvement. The trees of the *dehesas*, litterfall, supply very large amounts of humifiable material to the upper soil horizons lying beneath its crowns.

Fertilization. The trees of the *dehesa* extract large amounts of nutrients from the deeper soil horizons, inaccessible to the herbaceous vegetation, and bring it to the upper horizons. Thus they have a true pumping and fertilising effect in two ways: one direct, through llitterfall, and the other indirect, by means of the phytophages. The fertilising effect of the trees can compensate, at least in part, the nutrient export due to the exploitation of the *dehesas* by livestock.

Animal concentration point. The trees of the *dehesas* are concentration points for animals, particularly domestic livestock, with the resultant effects of trampling, fertilising, overgrazing, seeding, etc. Depending on the density of the tree cover, these can range from almost imperceptible, to beneficial, or even to harmful (with the appearance of ruderal communities, and even the disappearance of pasture beneath the most favoured trees).

Reduction of surface available for pasture. The presence of dead leaves and other vegetable waste from the tree on the surface of the soil reduces in proportion the soil surface available for pasture.

Diversification. The presence of the tree population increases environmental, and therefore the biological diversity of the system, and makes an important contribution to the greater stability of the system.

Apart from its ecological function, the tree population of the dehesas also plays directly productive roles: browse, wood, fruit, cork, etc. How important these are depends on the environmental conditions, the typology of the *dehesa* in question and the treatment it has been subjected to.

The comparison of the positive and negative effects of the tree population of the *dehesa* and its productivity, in relation to the thickness of the tree cover, has enabled researchers to propose optimal densities and spacings for trees in different types of *dehesa*. Although this depends on the characteristics and particular objectives of each of the types described, we consider that the norms proposed by Montoya (1987) for typical Mediterranean *dehesas* have the advanta-

ge of providing us with a very reasonable and widely applicable set of figures. Tree density in marcescent and deciduous *dehesas* is usually considerably greater due to differences in structure, function and exploitation.

Pastureland

In a simple way, the most important Mediterranean *dehesa* grasslands on poor soils can be grouped into four broad categories: general annual grassland, dense grassland improved by grazing and consisting of annual and perennial species (*majadales*) and edaphohygrophilous grasslands (*vallicares* and *bonales*), and fodder crops.

General annual grassland

This belongs to the more degraded stages of the *dehesa*'s climax vegetation community, and has been stabilized by grazing and/or temporary cropping. This is a mainly an annual grassland, whose main characteristics are small height, short life and wide extent (it usually covers most of the *dehesa*). These grasslands are normally included in the suborder *Bromenalia rubenti-tectori* (subnitrophilous annual grasslands called *posíos*) or in the class *Tuberarietea gutattae* (normal annual grasslands).

Most of the primary production of the general grassland on the Mediterranean *dehesa* is during spring and autumn - the latter period producing considerably less, or possibly even nothing at all. Parching begins early - at the end of spring; autumn productivity depends heavily on the autumn rainfall - when it occurs, and how much; there is little or no productivity in winter, due to the cold (Gonzalez Aldama and Allué Andrade, 1982; Cañellas *et al*., 1991; Granda *et al*., 1991; Yañez *et al*., 1991). The main function of general grassland is to supply livestock with most of its diet during the good periods of spring and autumn, and to complement other fodder through the rest of the year.

Within the *dehesa*'s general grassland there may arise other typologies of great importance for the operation and stability of the *dehesa*: communities existing either underneath, or away from, the trees. The marked influence of the tree population of the *dehesas* produces very significant environmental modifications under their cover: modifications involving differences in the flora and the reaction of the grassland. Thus under the treecover the growing season is longer, there is greater abundance of perennials, and the composition of the flora is distinctive - with more demanding and higher quality woodland species which would be unable to withstand exposed situations except in very favourable years (*euroatlantization*, according to Allué Andrade). Thus the grazing available under the trees increases the diversity of the general grassland and acts as a shelter and centre of dispersal of species; it is, as Montoya (1983) points out, a cohesive element in the *dehesa*.

The *majadal* (communities of *Poetalia bulbosae*) is found in places preferred by the livestock. The stand should have low density and grass production is high in both quantity and quality. In the picture a cow of autochthonous breed (*retinta*), bred from *Charollais* , and some hybrid calves.

In the small valleys appear very productive communities of high grasses. Dry grass can be seen on the small hills and intensive green of the valley beds (*vallicar*).

Optimum grassland consisting of annual and perennial species (Majadal)

The *majadal* (communities of *Poetalia bulbosae*) may be described as a very dense grassland of annuals and perennials, of low height and generally of high nutritional value, created by intensive and continuous livestock activity and with a high proportion of *Poa bulbosa*. Its creation is due, as well as to intensive and continuous grazing, to the edaphic amelioration (improvements and fertilization) produced by the livestock with nutrients gathered from all over the pastureland. From this point of view it is, as Montoya *et al.* (1988) point out, a parasite in its environment. By their very nature, the *majadales* are found in the places preferred by the livestock - whether these are natural or artificially managed by man. Thus their growth can be encouraged or their surface area increased by techniques such as penning, perhaps complemented by phosphorous fertilization, and the depositing of supplementary fodder or concentrates at certain locations (INIA/SEA/ADG, 1984).

In spite of its small size, its yield in dry material is greater than that of the

general grassland because of its very high capacity to produce new shoots. Its palatability or attractiveness is also very superior to that of the general grassland, as are its nutritional qualities, because subterranean clover and other leguninous species greatly increase the average protein content of the pasture. However, the importance of the *majadales* does not lie only in their productive qualities, but above all in their strategic value, which is determined by two factors: in spring the subterraneun clover dries up quite late, and provides a very significant amount of digestible nitrogenated material to the livestock at the very time, during the lactation period, when protein need is highest; in autumn, *Poa bulbosa* is the fastest-sprouting species after the first rains, and therefore the one which decides when the period of autumn grazing shall begin and when artificial feeding shall be brought to an end. We can thus say that the *majadales* are the most valuable grassland on the *dehesa*, and for this reason a lot of the graasland management goes into increasing the area of *majadales*.

Edaphohygrophilous grasslands (vallicares and bonales)

The mostly hilly topography of the *dehesas* produces valley beds and hollows where seasonal phreatic phenomena of greater or lesser intensity are more frequent, and where edaphohygrophilous communities make their appearance. Upon oligotrophic soils, grasslands in these areas consist mainly of perennials, many high grasses, and few leguminosae. They have a very late phenology, flowering at the end of spring and withering in the middle of summer. Their common name is *vallicares*, and from a phytosociological point of view, they can be included in the order *Agrostietalia castellanae*. Their grazing value is only average, since though their productivity is high, their palatability and nutritional quality are not (the scarcity of leguminsosae implies low digestible nitrogen content). Even so, their late phenology gives them an important strategic role as natural high summer grazing, since in the typical Mediterranean *dehesa* environment they are the only grassland type which stays green for a large part of summer, and, if they receive water, may avoid being dried out. For these reasons, they can help greatly to reduce the summer fodder shortage period, thereby reducing the owner's costs and increasing the *dehesa*'s chances of self-sufficiency.

Fodder crops

The occurrence of low food availability periods in the *dehesas* often leads their owners to try to sidestep their effects by means of forest treatment (bringing forward or postponing pruning or thinning of standards), or establishing artificial pastures and/or herbaceous fodder crops to be used in these periods of shortage. Since the problem periods are summer and the end of winter, the fodder crops most commonly used in the *dehesa* are barley, oats and wheat, for their dry grain in summer, and rye and oat, to be eaten green at the end of winter and in

The *dehesa* is a system where a multipurpose management is easy to apply. Different types of livestock are usually employed in order to make best use of the varied resources. In the picture we see a *dehesa* grazied by sheep.

spring, vetch-oat for haymaking, and the growth for fodder of annual gramineae, such as *Lolium multiflorum* for hay or silage. Nowadays there are attempts to plant fodder shrubs, generally rich in digestible nitrogen material, which might provide reserves of green fodder and rotational feeding in times of food shortage.

Livestock

Livestock is the main direct product of the *dehesa*, and, as in most forest systems, it is also the main instrument of stabilization, perpetuation and improvement of the whole system. We can make a simple outline of the main functions of livestock in the *dehesa* as follows:

- Keeping back invading scrub
- Improvement of grasslands
- Transportation of fertility
- Acceleration of the nutrient cycle

Given the ecological and productive diversity of *dehesa* systems, it is common to find them used for different kinds of livestock: sheep, cattle, pigs, goats, horses and so on, in order to make best use of their grazing. Naturally, the different ethologies and feeding preferences of the varied livestock have different effects of the vegetation communities of the *dehesa*.

The external structure of the *dehesa*

The pronounced summer drought which is characteristic of the typical Spanish *dehesa*, and the winter cold, ensure one period of lack of food and another of reduced availability. At times, the problem of winter can be lessened by the food supply from fruit (acorns), and tree browse (internal integration). Generally, however, the *dehesas* cannot be self-sufficient, at least in summer, and depend on livestock feed from other neighbouring systems or from fodder and concentates brought in (external integration). The most common solutions

in these cases are as follows:

- Transhumance or transterminance (short trashumance)
- Use of residues from arable farming
- Use of fodder and concentrates brought in

Goats grazing in *dehesa*.

Whether or not the owners use one of these solutions, they usually reckon also on playing with another variable - the hunger of the livestock. Bearing in mind that the main product of the different livestock on the *dehesa* are their young, and that in order to obtain these it is only necessary to keep the stock in optimal condition during the mating period, gestation and lactation, the owners usually try to save expense by allowing the animals not to cover all their energy and protein needs during the lean grazing periods. The animals thus lose body condition, fat reserves, at least as far as a point below which recovery would be difficult and costly.

Other measures which may be adopted to avoid bringing in fodder or concentrates in periods when grazing is scarce are the concentration of the rut in such a way that births will take place at the most favourable times, and the reduction of the lactation period by early weaning. These measures, however, are only acceptable if the market and sales opportunities allow.

Another factor is that the *dehesa* is usually neighboured by woodland and Mediterranean scrub formations on which it depends in two senses: as a shelter and food source for game (one of the most important direct products of the *dehesa*) and as protective and stabilizing formations.

The importance of external integration in the *dehesa* means that any ordered attempt to investigate its management must fully examine not only the characteristics of the *dehesa* itself, but also those of the neighbouring agro-silvo-pastoral systems.

PRODUCTION AND MANAGEMENT

The detailed analysis of productivity is one of the most complex tasks faced by economists of the *dehesa* (Campos Palacín and Abad, 1987). Therefore, alt-

hough we may be oversimplifying the situation, we consider that for didactic purposes the productivity of the *dehesa* may be grouped into three broad categories: indirect productivity, capital gains, and direct productivity.

Indirect productivity

Without doubt the most important product of the *dehesa*, as in other forest systems, is indirect - in one word: stability. The *dehesa* is an agrobiosystem stabilized for the purposes of management at a stage close to that of the original forest, and having great diversity. For this reason its indirect productivity is very high. Among the most important benefits are its high recreational and landscaping value, its role in protecting soil and vegetation in a climatically and lithologically difficult environment, its maintenance of important genetic capital, its enormous historical and cultural value, and its low fire risk in comparison with other forest systems.

One of the main drawbacks of this indirect productivity is that it is general (Meson *et al*., 1987), in the sense that while society as a whole benefits, it does not offer much to the owners of *dehesa* (most of which is in private hands). It is therefore important that the authorities, bearing in mind the low capital fluidity of these systems compared to their fixed worth, and the resultant difficulties in financing treatment and improvement, collaborate in their upkeep and improvement not only economically (which might even turn out to be detrimental to the land), but also by offering technical assistance and control. It is important for society to collaborate in the upkeep of the *dehesa*, but also to keep track of allocated funding, so that this cannot be used in wrong or fraudulent ways against the interests of the system, as does unfortunately happen to some extent at present.

Capital gains

So far, studies carried out on the economy of the Spanish *dehesa* (Campos Palacín y Abad, 1987) have shown that their current profitability is due less to income from its direct productivity than to the capital appreciation or increase in market value of the estates. This fact, closely linked to the comparative insignificance of capital fluidity in relation to fixed worth, poses a serious problem, as we have already mentioned, for the survival of the *dehesa*. It has two very negative effects:

- It encourages those owners of *dehesa* interested only in obtaining economic profit not to concern themselves with a rational exploitation of its resources. In this way, it leads to the neglect or poor management of the resources of the *dehesa*.
- It implies lack of capital to finance the treatment and improvement which are needed in order to exploit direct products - livestock, firewood, browse etc. - in a rational way. Bearing in mind that these, in turn, guarantee the

system's stability, neglect or poor land usage may bring about the disappearance of the *dehesa*.

Iberian pigs grazing in *dehesa*. These bring high economic profits because of the value of their meat products.

Direct productivity

Nowadays the direct products of the *dehesa* are perhaps the least important, whether from an economic or an ecological point of view. However it is these which guarantee the system's survival and which allow owners or tenants to make a living from them. Their importance is therefore also high. The main direct products of the *dehesa* are as follows:

Cattle grazing in *dehesa*. Breeds used are generally rustic and native, in this case black *avileña* cattle.

Livestock

The *dehesa* is an agro-silvo-pastoral system exploited fundamentally for livestock raising. Its systems of exploitation are what Prof. Montserrat has termed "routines", that is to say ecologically-based techniques developed, perfected and handed on over the centuries by the stockraising cultures which have used it to survive. Naturally these techniques are perfectly adapted to the obtention of optimal benefit from the environment without harming it; they are therefore an extremely valuable cultural inheritance which it is necessary to recuperate (because it is disappearing), study, and leave for future generations.

Livestock raising systems on the *dehesa*, in the main extensive, are based upon a

Hunting yields high profit in the *dehesa*. In the picture, deer grazing in a Mediterranean shrubland.

Deer live in the Mediterranean shrublands during the day, moving into the open woodlands during the evening to graze their pastures.

diversity of production, and thus different types of livestock are usually uses in order to make best use of the varied resources. the types of livestock most commonly used are as follows:

• **Sheep**. For meat products. This is certainly the stock most suited for the exploitation of most *dehesas*. The most typical breeds are rustic, like the merino. Nevertheless, there has been a tendency to semi-intensify the exploitation by fodder supplementation, and by attempting crossbreeding with other more productive breeds with better meat quality, like the early merino, the Romanoff, the Fleischaff or the Landschaff, generally in cycles of three births within two years. Although this is still a matter of hot debate among livestock farmers, both European Union agricultural policies and the need to produce at minimum cost while maximizing yield from the resources of the *dehesa* would indicate the use of rustic breeds-though of high quality, with a reproductive cycle of one birth per year. Grazing is usually at a rate of one to three sheep per hectare in normal *dehesas*, though with a good programme of exploitation and improvement of the grassland (Muslera, 1984; Pérez, 1988; Penco, 1992; Olea and López-Carrasco, p.c.), this can be raised to 3-4 sheep/ha. Even so the sheep usually need to be fed with concentrates during times of maximum nutritional need (lactation and the last month of gestation), above all, as is the case in the semi-intensive exploitations of three births per two years, when these times fail to coincide with periods of plentiful availability of natural feed.

Sheep farming is favoured by the demand for its products in the European Union, and, at the moment, by government subsidies. These factors have led to a sharp increase in sheep population over the past few years. Disadvantages include the need for a shepherd (not necessary for cattle, for example), and recent imports from the Commonwealth and Eastern Europe.

• **Cattle**. For meat products. Suitable for less dry *dehesas*, there was a marked increase in their use some years ago because they do not need anyone to guard them, they are easier to handle and need less attention from their owners who, thus, can be part-timers. The present policy of subsidising sheep farming has reversed this tendency. The breeds used are generally rustic and native: the avileña in the Sistema Central, the morucha in Salamanca and the retinta in the warmer *dehesas* of the south. For economic reasons, however, crossbreeding is common with imported breeds of better meat quality, such as Charolais and Limousine. Grazing on the *dehesa* is normally at a rate of one cattle unit per 3-4 ha.

• **Pigs**. These are fundamental for exploiting the acorn or yield (*montanera*) in *dehesas* with warmer winters, though they can also take advantage of pasture without digging if their snouts are ringed. The most common breed is the Iberian, which is usually put onto the *dehesa* in October-November, at eight to ten months old and 60 - 80 kg. weight, and taken off in January with 120 - 160 kg. normally without any supplementary feeding. The main problems of this breed, which though rustic has excellent future prospects, and which a few years ago could on its own guarantee the profitability of the *dehesa*, were African swine fever and great fluctuations in its sale price.

• **Goats**. These are often used as a complement to other kinds of stock in order to make better use of woody fodder: scrub and browse. Breeds for meat, dairy or mixed purposes may be used. Their correct management can help to keep back the invading scrub, but if browsing is not carried out correctly this can become an important degrading factor, halting natural regeneration of the vegetation. Normally, in areas of *dehesa* with a large proportion of scrub, two to three goats are kept per hectare; their feed is supplemented with concentrates during the last phases of the gestation period and throughout lactation. It is usual to try to achieve three births per two years, with births at the end of autumn, in summer and early spring.

• **Horses**. Although these are highly adaptable to *dehesa* conditions, their limited commercial value means that these are rare in this agrobiosystem, except as a complement to other kinds of stock, though occasionally they are raised as thoroughbreds.

The grazing system most suited to the majority of *dehesas* is continuous, because of the low quantity and seasonal variability of its primary product. In overgrazed pastures or where there are dissemination problems it may be advisable to used delayed grazing, in other words waiting a certain time beyond the optimal time from the point of view of quantity and quality of pasture. In this way the annuals - the most numerous species in *dehesa* pastureland

Holm oak browse is an important resource for feeding livestock. In the picture, a cow browsing on holm oak.

- are allowed to flower, fruit and disseminate. Nevertheless, as Montoya (1983) points out, grazing in Mediterranean areas, including the *dehesas*, should normally be early, in order to reduce initial competition from the least valuable species against the more valuable, intensive (though not excessively so), in order to benefit the species of highest grazing quality, which not only withstand grazing better but are actually favoured by it, diversified with regard to the kind of livestock and the systems exploited, so as to take best advantage of the environment's productive diversity, and integrated with forest systems (woods, scrub, etc.) and farming systems (cereal and fodder cropping, agricultural by-products, etc.) to make up as far as possible for the *dehesa*'s lack of self-sufficiency.

Browse

Browse from the trees of the *dehesa* can be gathered directly by the livestock by browsing or indirectly, from branches pruned or beaten down with poles for acorn gathering. The first is very common incoppice *dehesas*, but less so in high forest *dehesa* where pruning and beatings are more common.

A rational pruning can yield up 300-500 kg/ha a year of dry browse material (about 550-900 kg fresh), while acorn-beating can add another 60-90 kg/ha dry, (about 90-140 kg fresh) (Cañellas *et al*., 1991).

Browse may be regarded as a permanent food reserve to be used at any moment when green grass is scarce. However, because of the pruning and beating seasons, the periods of lack of grass, and the preferences of the livestock, it is common to use it mainly at the end of summer and, especially, through the winter. The food value of the browse varies with its phenology, though in relation to energy, it may stand at around 0.2 UF/kg (fresh). The most suitable stock for making use of the browse of the *dehesa* are goats, followed by cattle, and to a lesser extent horses and sheep. This type of food is also consumed in high quantities by larger game (Rodríguez Berrocal, 1978; Palacios *et al*., 1980; Caballero, 1985; Rodríguez Berrocal and Molera, 1985; Fandos *et al*.,1987; Álvarez and Ramos, 1991a,b; Álvarez *et al*., 1991).

Fruit

The *dehesa* trees are pruned in autumn-winter to complement livestock fodder. The picture shows some goats browsing on cork oak prunings.

The most characteristic fruit of the *dehesa* is the acorn, which is extremely important in areas of mild winters. The fact that acorn production on the *dehesas* tends to be concentrated on a limited number of trees has led to research being carried out into the study and selection of most the productive individuals or varieties with a view to their eventual reproduction and use in reforestation projects.

The acorn with the highest nutritional quality is that of the evergreen oak, followed by those of the quejigo, cork and rebollo oaks, reckoning with (Rupérez, 1957) 9 kg of evergreen oak acorns being equivalent to 12 kg from the quejigo oak, 14 kg from the cork oak and 18 kg from rebollo or common oak. As fodder, the acorn is poor in proteins and rich in carbohydrates which are easily transformable into fat. It is therefore usually used for fattening fully-grown animals. Its energy value is about 0.5 UF/kg. The stock which make best use of the *montanera* (acorn-feeding period) on the *dehesa* are pigs, particularly of the Iberian breeds, which transform approximately 7-9 kg of acorns into 1 kg of high quality live weight, consuming about 8-10 kg of acorns per day for each 100 kg of live weight, all within an extensive system of exploitation, and generally without supplements. For other livestock, the *montanera* is only a complement of varying degrees of importance in its feeding.

In spite of the variability in acorn yield on the *dehesas*, we can offer as reference an average, for the fruit-bearing evergreen oak *dehesa* (whose surface Montoya, 1989, has estimated at more than 1,200,000 ha) of around 500 kg/ha per year, rising to 800 kg in some cases. Figures of about 300-400 kg/ha could, however, be regarded as acceptable. Exploitation of the acorn, whether through natural fall or after beating down, is usually in the October to January (inclusive) period, though the first to fall are usually green are usually green (with a high tannin content which may affect the livestock) or affected by *Balaninus* spp. Acorn ripening is earlier on the quejigo than on the evergreen oak, which in turn is earlier than on cork oak. On the latter species there are three maturation periods: September to October, October to November and December to January, yielding acorns which are called *migueleñas* or early, *martinencas* or middle and *palomeras* or late.

Acorns are a product rich in carbohydrates and lipids. They are produced in autumn and are excellent fodder for Iberian pigs. For the other livestock, the *montanera* is only a complement of green and fresh grass, rich in protein, produced with the autumn rainfall.

Arable crops

The products of the *dehesa* from arable farming, normally cereals like oats, barley, rye or wheat are usually of small importance, and, as we have mentioned, are not only produced as primary farming crops, but also for livestock fodder. We shall therefore not enter into detail on this matter.

Others

Game is one of the most direct benefits of the *dehesa*, and has also great prospects, since it is, according to the agricultural guidelines laid down by the EEC Council of Ministers of Agriculture (ICONA, 1989), a quality product totally compatible with environmental conservation and with very small demands on time, means or money. For the time being, the most important measures which can be taken along these lines must surely be to fully appreciate the potential of game as one of the products of the *dehesa*, and to organise its exploitation in a rational, and, of course, sustainable way. With this in mind, it is worth remembering that there are currently problems arising from indiscriminate attempts to intensify productivity in this area. Among these we would stress the frequent lack of tree regeneration caused by excessive big game populations not only in the *dehesa*, but also in neighbouring forest systems in the Mediterranean region, and also the sanitary and genetic problems caused by the uncontrolled transference of animals (partridges, deer, etc.) between hunting farms.

On cork oak *dehesas*, cork is a highly important product whose economic potential has increased markedly in the past few years. The fundamental norms for its exploitation, usually in 9-12 year rotations, can be found in Montoya's (1988) book on cork oak *Los alcornocales*, and in various investigations carried out as projects for the Instituto Nacional de Investigaciones Agrarias: Montero (1987, 1988), Montero *et al*. (1991, 1994), etc.

Finally the *dehesa*'s varied mushroom products have traditionally been exploited in a private, non-intensive way. Nowadays, however, their economic attractiveness is rising, both from the point of view of private or semi-industrial profit from naturally-growing fungi: truffles, boletus, and various kinds of mushrooms (Oria de Rueda, p.c.), and as an artificially introduced crop, particularly in the case of truffles (Rodríguez Barreal, p.c.).

Density of tree population

The density of the tree layer influences grass production. High density may reduce production, but very low density does not increment the grass production in quality or quantity. Cork production in cork oak *dehesa*s may make it advisable to maintain higher densities that those in holm oak *dehesa*s. In this picture we show a cork oak *dehesa* with over 65% crown cover and where the grass production continues to be very high.

The determination of the most suitable density for optimizing the productivity of the *dehesa* is a controversial and under-researched topic in our country. The peculiar combination of products (cereals, grazing, browse, firewood and *montanera*), the influence of the treecover on production and the specific characteristics of the grassland make determination of an optimal density difficult. This would also vary from estate to estate according to the degree of reliance on the *montanera* or grazing.

Since we do not have sufficient experimental evidence to allow us to determine precisely an optimal density for each *dehesa*, we will attempt to approach the problem on the basis of the limited bibliography available (Rupérez, 1957; González Doncel and Gómez, 1980; Montero *et al.*, 1991), and of our own modest experience. We shall try to estimate the upper and lower limits of density for the purposes of maximizing productivity.

Since holm and cork oak *dehesas* are those occupying the widest area, we shall in this section concern ourselves solely with these.

In well populated holm oak *dehesas*, or in cork oak *dehesas* where production of livestock food is important, the maximum yield of acorns and grazing is obtained with a density of between 30 and 50% of the surface under the treecover (Vázquez and Montero p.c.).

The number of trees per hectarea varies according to their size, and should relate to the figures in Table 1.

Table 1. Variation in number of trees/ha according to diameter class

Diameter class (dbh, cm)	Nº trees/ha	Diameter class (dbh, cm)	Nº trees/ha
20 - 29	125 - 175	50 - 59	40 - 50
30 - 39	75 - 110	60 - 69	30 - 40
40 - 49	50 - 75	> 70	30

For cork oak *dehesas* where cork is the main product, the density should be greater (Table 2).

Table 2. Variation in number of trees/ha according to diameter class for cork oak dehesas where the main product is cork

Diameter class (dbh, cm)	N° trees/ha	Diameter class (dbh, cm)	N° trees/ha
20 - 29	200 - 250	50 - 59	75 - 85
30 - 39	125 - 175	60 - 69	65 - 75
40 - 49	85 - 100	> 70	60

Regeneration of the *dehesa* is an important element in its survival. Exhaustive exploitation of the *montanera*, continuous grazing and periodic ploughing have resulted in the ageing of trees, preventing young trees from replacing very old ones, such as those in this picture. Note the rot in branches and trunk due to pruning of these trees.

Regeneration

The low regeneration rate of *dehesas* is an undisputed fact. A solution to this demands is a correct diagnosis of the causes limiting regeneration or making it impossible, and a true evaluation of the present and future consequences which lack of regeneration could have on the economics of exploitation and on the very survival of *dehesa* systems. On the basis of this analysis it will be necessary to find solutions which, while compatible with the present system of exploitation of the *dehesa*, will allow their regeneration in technically and economically viable ways.

Lack of regeneration - origin and consequences

The main problem affecting the *dehesa* is insufficient natural regeneration, a vitally important factor in its survival prospects. The lack of regeneration in most *dehesas* is obvious; at best there are not enough young trees which in future could take over from the adults of the present day.

Silvopastoralism, or the scientific management of these *dehesa* systems, must respond to this problem.

In most *dehesas* livestock production has overshadowed the economic importance of the trees. As a result most owners have had little interest in regeneration, seeing it as a very long-term problem, and do not pay heed to it, even though it is the greatest problem currently facing the *dehesa* - so great that in many cases it threatens their very existence in the short or medium term. All too often owners see regeneration as a competition between their stock and the trees, instead of understanding it as mutually beneficial, as it really is in the *dehesa* system.

It is worrying to find that in practically all our *dehesas*, which sometimes look so splendid, are exclusively populated by trees which may be old or very old, but which have hardly a seedling or a young standard growing under them. New individuals to substitute those which die are not being produced.

Exhaustive exploitation of the *montanera,* periodic ploughing and scrub clearance, as activities carried out unselectively, inevitably finish off the few seedlings of evergreen oak, cork oak or other species which have managed to survive the harshness of the climate. It is clear that these are the causes which prevent the regeneration of the *dehesa*, and that if they are not stopped or reduced it will not be possible to regenerate large areas of *dehesa* regularly and by natural means. So if the *dehesa* has existed since the time of the Reconquest (from the Arabs), as much evidence would suggest, we might ask how they have survived until now.

We believe that the *dehesa* system, more or less similar to that of the present day, has indeed existed since that time, but that at first the creation of *dehesas* must have been restricted to regions which were more fertile and more productive in grazing and cereal. Little by little these became completely treeless through clearing or lack of regeneration, and are now given over to pasture, cereal crops, or to permanent *posíos* producing sparse or seasonal grazing. The creation of *dehesas* shifted gradually towards less fertile areas unsuited to agriculture - those areas where we nowadays find most *dehesas* or woodland grazing. If correct, this assessment would lead us to the conclusion that our *dehesas* are still in their first cycle after their original creation, in other words, that they have never regenerated. The old trees surviving in them are the young ones which existed at the time of the *dehesa*'s creation. If, as Fragoso said (1790, quoted by Vieira, 1950), the creation of *dehesas* in the Alentejo area of Portugal began around 1750 with greater intensiveness and with similar composition, structure and form to those of the present day, it is reasonable to suppose that things were similar in most of Extremadura, an area very close in both geographical and socioeconomic terms to this part of Portugal. This would mean that most of our *dehesas* date from this period, and that as a result the problem of aging trees and the need for regeneration did not arise till the early or middle twentieth

Robles (1961), referring to the need for cork oak century said: "there is still a lack of awareness of the problem, and it is necessary to act urgently if we wish the *dehesa* system to survive".

Robles (1961), referring to the need to regenerate cork oak plantations, said: "New tree growth is essential to the existence of forest or *dehesa*. It is as much

*Dehesa*s can regenerate with relative facility but need to be fenced off from grazing for a number of years, depending on the type of livestock. In the picture, year-old cork oak seedlings are shown. These seedlings will grow if they have enough light and are not browsed by livestock.

part and parcel of land ownership as is machine amortization in industry. Machines and trees are finite resources, and need to be replaced if the productive unit (the *dehesa*) is to survive. Machinery, however, is built in a matter of months, whereas the building of a tree takes nearly fifty years. Thus we have to begin today if we are to fulfill the needs, half a century hence, of production, protection and biodiversity".

Natural regeneration

Experience shows that evergreen and cork oak *dehesas* regenerate by themselves with no other intervention than the fencing off of livestock and game for periods varying in length on the silvopastoral conditions of the *dehesa*, and the type of livestock grazing it. The many examples of estates "abandoned" either by absentee landlords or for other reasons confirm this. This proven fact would indicate that the problem could be solved by the simple means of fencing off selected areas of the *dehesa* to prevent grazing over a period not always exactly definable.The problem is that the lack of grazing results in the lack of grasslands through natural sucession.

Owners are reluctant to take these measures for fear of giving up a proportion of the small income afforded by their exploitation of the estate. They do not, however, take into account that in the long, and in many cases the medium term, they are risking the survival of the system and lowering the quantity and quality of their livestock production.

Silvopastoralism has the right tools to ensure the regeneration of the *dehesas* without imposing immediate heavy financial burdens on the owner. Procedures are simple and consist of defining the following:

- The desired cycle or period of rotation for complete regeneration of the *dehesa*. In principle this period could be set at 120 years.
- The period of time in which the areas undergoing regeneration need to be wholly or partly fenced off (regeneration period)
- The division of the estate into as many plots as result from dividing the rotation period by the regeneration period (120 ÷ 20 = 6 plots, in which case

each plot would consist of about 17% of the *dehesa* area needing regeneration).

- The selection of the areas in most urgent need of regeneration, whether because of loss of trees or because their trees are the oldest, up to a proportion of 17% of the whole estate. These areas do not need to be contiguous.
- The fencing-off from grazing of the decided 17% of the whole, to be termed the regeneration area or plot.

This method, which in principle means forgoing the use of 17% of the estate for twenty years, might be made more flexible given sound knowledge of the estate and if there are yearly inspections of the regeneration plot.

By the fourth or fifth year after fencing, there will certainly already be enough plants seeded from acorns around the mother trees; this would allow advantage to be taken of the *montaneras* from this period on for pigs, who eat the acorns without causing too much damage to the young plants which will provide the regeneration. Sheep grazing can also begin in a moderate way, after five or six years and at times of abundant fresh grass (mainly in autumn and early spring), when the sheep does not usually concern itself with young plants, so there is not much harm done from browsing. Goat or cattle grazing is not recommendable until after at least fifteen or twenty years.

Once regeneration around the mother trees has been achieved, these will be gradually eliminated to free the new growth from their competition; shoots and seedlings which have grown to 1.5 metres or, and which because of their vigour and space arrangement are to be selected as future trees on the *dehesa*, will be pruned.

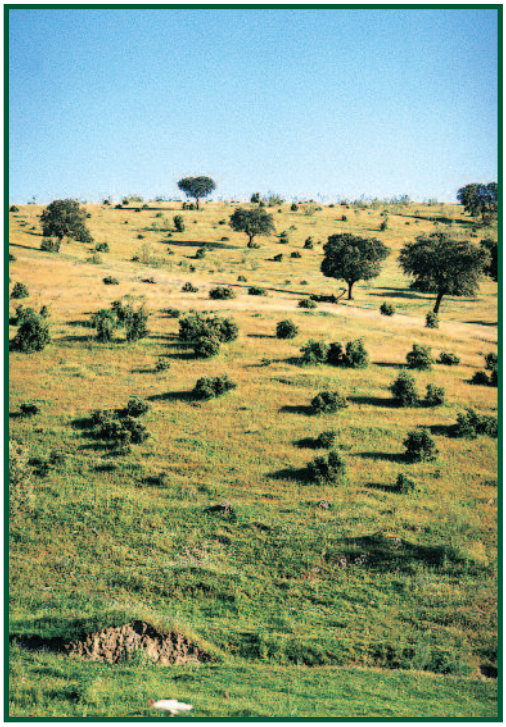
If, as often happens, the spaces between trees have not had new growth, there will be no option but to turn to artificial regeneration, along the lines laid out in the next section.

When the whole plot is sufficiently regenerated, it will be reopened for grazing, subject to any precautions which may be advisable. Other plots will then be fenced off, according to the degree of need for regeneration, and so on until the whole estate has been regenerated.

Any loss of income which the owner might have incurred can be compensated by pasture improvements in other parts of the estate, which are traditionally subsidized by the forestry authority.

In many *Quercus pyrenaica* and *Q. faginea dehesas*, situated mainly in the provinces of Salamanca, Avila and the north of Cáceres, in the lands at the foot of the Sistema Ibérico and Sistema Central, and in parts of the province of León, it is common to find *dehesas* which have been, or are being regenerated by means of shoots from stock and root (standards). Some of these *dehesas* in formation were, until forty or fifty years ago, coppice used for firewood, clear cut every 15-20 years.

In evergreen oak *dehesas*, if there is insufficient regeneration by seeding, this method of renovation is often adopted. This system, although it can be found on *dehesas* throughout Spain, is more common in Castilla-León and Castilla-La Mancha than in Extremadura and Andalucía.



Regeneration by stump and root shoots could be a short-term solution for the *dehesa*. In the picture livestock are shown browsing on shoots of holm oak. If the grazing were eliminated, these shoots would grow very quickly and could form a standard *dehesa*. The disadvantages of this are the shorter life of these trees in relation those produced from seeding, and their smaller size.

In this method tree regeneration is brought about, after the felling of adult trees, by means of shoots from stock and root. In this way the root systems of the trees do not die, and their spread and vigour encourage abundant and vigorous shooting; this means that these areas can support some grazing (never intensive, if the aim is to achieve a good regeneration of the area).

In this case, and if browsing is not very intensive, standards are usually distributed in groups or small patches, and acquire a scrublike form, chewed to a greater or lesser degree by rabbits and haves (in the case of the evergreen oak). If the ratio of production to herbivore consumption is negative for the plant, this will remain virtually in the form of a creeping shrub, much browsed by the livestock over many years, and will finally die if livestock pressure is not stopped or reduced. If, however, as is usually the case in coppice, the balance is positive, then the volume of the brushwood increases until its central part is physically inaccessible to the livestock, and from this central area spring those individuals which begin to gain height, producing new trees which will form the woodland of the future *dehesa*. When these individuals have reached a certain height and girth (varying according to the type of grazing livestock, sheep, goats, cattle, deer, etc.), the next step must be the elimination of the remaining shoots of inferior quality and a light pruning of the selected individuals.

If the aim is to speed up the process or lower the risk of failure, it is advisable to fence the area off from grazing for a while, and to make a selection of shoots - earlier than in the previous case - in order to encourage growth in height free from the competition of inferior shoots and livestock browsing. Grazing can be resumed when the shoots have reached sufficient height and diameter to resist livestock browsing pressure (this varies according to the kind of livestock, as mentioned above). Some native breeds of cattle, such as the *avileña*, cause much harm to the bark of young trees by rubbing against them, and can even, in many cases snap off saplings of up to 10 cm dbh, either by rubbing against them or by bending them over, using their neck to eat the leaves and shoots of the crown. Roughly speaking, the fenced-off periods should vary between 2-3 years for sheep and 10-25 years for goats and cattle, according to grazing intensity and the abundance and development of shoots. Finally, it is important to mention that whereas the shoots from stock and root

grow in height much quicker, in their early years, than do seedlings, after 40-50 years - and according to the fertility of the land, the aging of the stock that comes from them, and the species in question - there is usually a slowing down of growth, and many trees begin to stop growing and dry out at the tip. This phenomenon is more pronounced in *Quercus pyrenaica* and *Q. faginea* than in cork oak, and in the latter more than in evergreen oak. In all cases the final size reached by trees stemming from shoots from stock and root is much less than that of trees grown from seedlings, and they very rarely live more than 70% of the average life for the species. This shows that although this regeneration method is common, and apparently simple and efficient as far as covering the surface with young trees is concerned, it should not be used other than where it is not possible to rely on regeneration by seedlings, or where, as is often the case, a mixed system is adopted, in which regeneration by shoots should not make up more than 30% of the individuals produced at the end of the process.

When the stump and/or root shoots have grown and have been pruned, they appear as in the picture. Their surface distribution in groups of 2-5 standards is characteristic of these communities.

Artificial regeneration

In *dehesas* with less than 20-25 trees per hectare, and with soil very much trodden down by livestock, natural regeneration is not usually enough, and it is necessary to turn to artificial regeneration.

Costings of artificial regeneration need to take three things into account: the cost of reforestation, the loss of grazing due to the fencing-off of the reforested plot, and the cost of cultivation and treatment of the plants - so necessary if we are to be sure that these are to take root and then develop properly. The length of the fencing-off period will basically depend on:

- the method of restocking
- the treatment applied to the new growth
- soil fertility.

We do not wish to enter here into the possible restocking methods advisable in individual cases, according to the particular ecology. Silvopastoralism

and exploitation of each estate, since these are relatively well known by the technicians who will have to oversee the work. We do, however, wish to point out that the less intensive the land preparation and plant treatment devoted to the new growth in its first years of life, the less will be the cost of these operations and the longer will be the time that the restocked plants need to reach sufficient size for the plot to be reopened for grazing, and the higher will be the risk of failure in reforestation. We would also draw attention to recent studies indicating that seedings and plantations of cork and evergreen oak carried out in cleared areas of the *dehesa*, without shelter from trees of scrub, are inviable without intensive soil preparation which will allow the plant roots to grow deep enough to ensure minimal moisture supply throughout the summer. Seedings and plantations laid in little hollows made with a hoe, with the intention of not reducing pasture growth, have proved to be totally unfeasible. More intensive operations increase costs at the early stages of stock maintenance, but shorten the periods of fencing-off from grazing, and, more importantly, considerably lower the risk of failure to take root or to proceed to acceptable plant growth.

If pasture production is very high and the owner is unwilling to fence the reforested plot, it is possible to opt for a reforestation by plantation, with soil preparation where necessary (though this must be intensive), low plant density (usually between 75 and 100 plants per hectare), and individual protectors for each plant (of different type and size according to the kind of livestock the plants need to be protected from). Restocking costs are higher, but use of the pasture can continue.

If pasture production is low, the reforestation should be collectively protected, by means of perimeter fencing of the repopulated plot in such a way as to prevent grazing for such time as is necessary.

In any case, if it is decided to restock by seeding, it becomes necessary to treat the acorns with one of the rodent repellants available on the market. Without this there is a risk that rodents will eat practically all the seeds; birds, too, can cause important damage by taking the acorns before their germination and by eating the shoots as soon as these emerge. Seeds for sowing will be gathered on the estate itself, where possible, and where not, from a provenance region with similar ecological characteristics to the *dehesa* to be restocked.

If it is decided to restock by plantation, the plants must be yearlings with a wide and well developed root system, cultivated in containers which avoid root twisting, and grown in as natural conditions as possible, with sufficient light. This implies that they must have spent as little time as possible in the greenhouse, that they are not overly long (a sign that they have not had enough light), that the leaves on the stem are together and all green from the base, that the consistency of the leaves is as coriaceous as possible (which shows that the plant has been toughened, and will have a better chance of rooting and survival in the climatically hostile environment usually prevailing on the *dehesas*).

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